

1924

Additional Water Supply of East Bay Municipal Utility District

1924 Report



A REPORT TO THE BOARD OF DIRECTORS

— By —

ARTHUR POWELL DAVIS
Chief Engineer and General Manager.

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MARSTON CAMPBELL, *Pres.*

JAMES H. BOYER

ALFRED LATHAM

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EAST BAY MUNICIPAL UTILITY DISTRICT

Comprising the Cities of Oakland, Berkeley, Alameda, Piedmont, San Leandro, Albany, Emeryville, El Cerrito).

BOARD OF DIRECTORS

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October 1, 1924

To the Honorable
Board of Directors of the
East Bay Municipal Utility District,
Oakland, California.

Gentlemen:

I have the honor to transmit herewith a brief report upon the Water Supply Problems of the East Bay Municipal Utility District and to recommend its publication for public distribution and information.

This report is the result of an intensive study of existing data which is very voluminous, and of field surveys and office computations and estimates made during the last four months by the engineers of this district.

These studies and preliminary estimates have been made for the purpose of selecting the best source from which to obtain a large additional water supply for this district, and are ample for that purpose. The estimates are general in character and made for comparative purposes. More detailed estimates, made upon the basis of designs of individual structures, must be made for construction purposes, and these are already under way.

Acknowledgments are due to the able and active assistance of Mr. James Munn, engineer in charge of costs and estimates; Mr. F. W. Hanna, who has superintended the preparation of preliminary designs and water supply studies, and has edited this report; also, to Mr. Wm. S. Cone, electrical and mechanical engineer, who has prepared plans and estimates for the power and pumping plants and other mechanical devices.

Acknowledgements are also due to the division engineers, Mr. F. T. Oakley, Mr. E. C. Mills, Mr. Geo. B. Sturgeon, Mr. J. S. Longwell, and Mr. C. E. Grunsky, Jr., who have carried on the field work and shown an energy and devotion to the work, without which it would have been impossible to prepare this information in so short a time.

In the brief time and with the meagre funds available to the General Manager for solving the water supply problems of this District, it would have been impossible to obtain satisfactory solutions had it not been for the large amount of data in evidence bearing upon this subject, and the generosity of those in whose possession the data are found.

First of all, should be mentioned the valuable topographic maps produced under the wise foresight and liberal appropriations of the State of California in co-operation with the United States Government. Though this one item is most important, it is exceeded in value and importance by many other data furnished from private sources which should be enumerated and appreciated. It might not be amiss to mention some of those who have most conspicuously assisted in this line, and many of whom have no interest in furnishing the information mentioned excepting the general public good of the District.

Mr. C. E. Grunsky, who has for many years been one of the most prominent and industrious students of water supply for the Bay Region, offered all that he has in his files.

Mr. C. E. Hickok, Manager of the City of Alameda, who has given a great deal of free services to the investigation of the water supply problems of the Bay Region, voluntarily turned over to this office a large collection of maps and reports on various sources, especially the Eel River. He also furnished a voluminous detailed report and study on the water supply of local sources which was of great value.

Mr. Cyril Williams has given freely the benefit of extensive and detailed studies he has made upon the ground water plane from which much of the water supply of the District now comes, and also a large volume of data on the detailed studies made by him of the water supply from the Tuolumne Basin.

Mr. Charles H. Lee has contributed the benefit of studies heretofore made on the needs of the East Bay Region and which are of value and interest.

Mr. M. M. O'Shaughnessy, City Engineer of San Francisco, has furnished a large amount of data on the Hetch Hetchy water supply and permitted the free use of his files for anything else of this nature needed. He has also promptly furnished very valuable cost data on the large pipe line now under construction by the City of San Francisco, which will be of great use.

The East Bay Water Company made available all of the detailed surveys of the Eel River route, and has offered the data concerning the quantity and quality of the water supply from the same source.

The Geological Survey, through Mr. L. L. McGlashen, furnished advance information on water supply wherever requested, and has gone to the expense of compiling and copying these data for the District's use. The topographic force of the Geological Survey has also been very courteous and furnished valuable information.

The U. S. Forest Service furnished the advance prints of the maps on the headwaters of the Eel River which were in preparation and not yet available to the public. They have also freely given us prints of the maps which are available to the public.

The U. S. Army Engineers furnished copies of contour maps of the region west of that cov-

ered by the Forest Service.

The engineers of the City Water Works of Sacramento showed, in great detail, all the plans and the works recently built there, explaining their operation and discussing all the minor points of difficulty that developed, which will be of great value. They also furnished a complete set of plans and specifications of these works and offered any additional information that is within their power to give.

The Chief Engineer of the Board of Water Supply of the City of New York furnished four volumes of detailed plans, specifications, and contract prices on a large amount of work for the City of New York which will be of great value in portions of the work.

The Chief Engineer of the Los Angeles Flood Control District furnished copies of specifications and contract prices on work under his charge which will also be very valuable.

The Southern Pacific Company turned over all their data upon the storage of water on the Rubicon and other portions of the American River Basin which had been obtained at considerable expense of field work.

Respectfully submitted,

ARTHUR P. DAVIS

Chief Engineer and General Manager



Report on Additional Water Supply for East Bay Municipal Utility District

INTRODUCTORY STATEMENT

The East Bay Municipal Utility District was organized May 22, 1923, and comprises the cities of Oakland, Berkeley, Alameda, Piedmont, Richmond, San Leandro, Albany, Emeryville, and El Cerrito. On page 7 there is a small map showing the boundaries of the District and of the cities within its limits. These cities are all served with water by the system of the East Bay Water Company and the district was formed for the purpose of acquiring this system and for bringing in an additional water supply from a suitable distant source. The district organization is the result of a great many years of agitation, study, and effort to bring to the East Bay Region an adequate water supply. In order to give a clear understanding of the water problem of these cities, it is desirable to consider the history of the present water supply system.

The Contra Costa Water Company, incorporated August 30, 1906, resulted from the consolidation, or purchase of 7 different companies, incorporated at various times from 1865 to 1900. Some of these companies were, in turn, the result of the consolidation of previously existing companies, so that not less than 12 different corporations were represented in the properties of the Contra Costa Water Company. Later this company was consolidated with the Richmond Water Company and the Syndicate Water Company into what was called the Peoples Water Company. The present East Bay Water Company is the result of a reorganization of the Peoples Water Company and the purchase of the Union Water Company. Thus, the present system is the result of the consolidation of many systems, separately planned, and in some cases more or less competitive.

The water supply was originally drawn mainly from wells and a few springs. These were supplemented by the construction in 1874 of Lake Chabot on Lower San Leandro Creek. Since that date this reservoir has been an important water source of the system, but a large portion of the present water supply is still obtained from wells.

That the water situation was considered critical as far back as 1907 is shown by the following quotation from the report of Arthur L. Adams, Engineer for the Contra Costa Water

Company: "The present demand for water is in excess of the sources of supply in the event of recurrence of such periods of scanty rainfall as have frequently arisen in the past." Mr. Adams recommended the development of temporary supplies to meet the emergency, which was accomplished by the construction of a number of wells in the Lower San Pablo Valley, but these wells were rapidly depleted, and the larger developments recommended by Mr. Adams were not carried out.

In 1910 the Peoples Water Company announced its intention of meeting the growing needs for water by the installation of meters, and, in a report to the stockholders in 1910, recognized the necessity of an increased supply, but proposed to take advantage of the Calaveras reservoir about to be built by the Spring Valley Water Company, and added the following statement: "Your Directors have reason to believe that the Spring Valley Water Company can furnish any amount that might be required on short notice, and at a fair price. Such action would still further postpone a large capital investment."

In 1918 the water shortage became so serious that irrigation of lawns and gardens was largely prohibited and many of them died. As a result of this shortage, there was constructed on San Pablo Creek a large reservoir with a capacity of 14,000,000,000 gallons and intercepting a drainage area of about 35 square miles. The reservoir capacity is beyond the yield of the basin in ordinary years and is designed to hold the floods of extreme years for use in drier years. It has never been filled since its construction, and will not be until the occurrence of several years of abnormal run-off. The present year is the eighth of a series of years of low run-off.

The Water Problem Committee of the Oakland Chamber of Commerce reported, in 1923, in part as follows: "Steps should be taken immediately, to secure at the earliest possible date a much greater supply of water than can be obtained by the fullest development of all local sources of supply, in order that the growth of the community industrially, as well as residentially, be not hampered."

When the spring of 1924 arrived, without the usual winter rainfall, the East Bay Water Company, appreciating that its reservoirs were very

low and that they could not be replenished for many months, increased its pumping facilities and is now providing pumped water from wells to the extent of about 20 M.D.G., or about two-thirds of the amount being delivered, the balance being drawn mainly from reservoirs on San Pablo and San Leandro Creeks. These reservoirs now contain less than 1,600,000,000 gallons, and the present rate of draft will soon empty them.

The heavy draft on the wells, together with the depletion of supply caused by the long dry period, has lowered the water plane in the pumping districts to an alarming extent. In the Alvarado region, from which most of the pumped water comes, careful observations have been taken upon five wells which are typical of the position of the water plane. Prior to 1918, none of these wells had ever shown a stage below sea level. In that year one of them went slightly below, but soon returned above, and all of them remained above sea level until 1920, when four out of the five were drawn below sea level during the dry season to the extent of about 7 feet. The water level in these wells returned to a stage above sea level in the spring of 1921. The same thing occurred in 1922, but in 1923 the water level in four of these wells declined below sea level; the winter of 1924 was so dry that the water level in all of them continued to decline under the gradually increased pumping demand.

The vigorous pumping that this region has received since March 1924, has caused the water plane steadily to decline until it is 15 to 20 feet below sea level in places. Unless the reservoirs are replenished by rain in the coming December, the pumping rate must be increased or there will be severe water shortage; and any increase in the pumping rate, or even its continuance at the present rate, threatens an entrance of salt water into the wells, as they are mostly located in the vicinity of San Francisco Bay. The situation is, therefore, extremely critical and unless the coming winter has much more rainfall than last winter, there will be a severe and disastrous shortage of water in the East Bay District.

Although the East Bay Water Company has undertaken the construction on Upper San Leandro Creek of a reservoir having a capacity of about 15,000,000,000 gallons, this reservoir cannot materially assist in relieving the present emergency, as it will require several years to construct the reservoir. The situation, therefore, demands vigorous and prompt action. Although the District may, by good fortune, escape imme-

diately disaster, it is very unwise, and positively dangerous for this community to continue under such precarious conditions regarding its water supply.

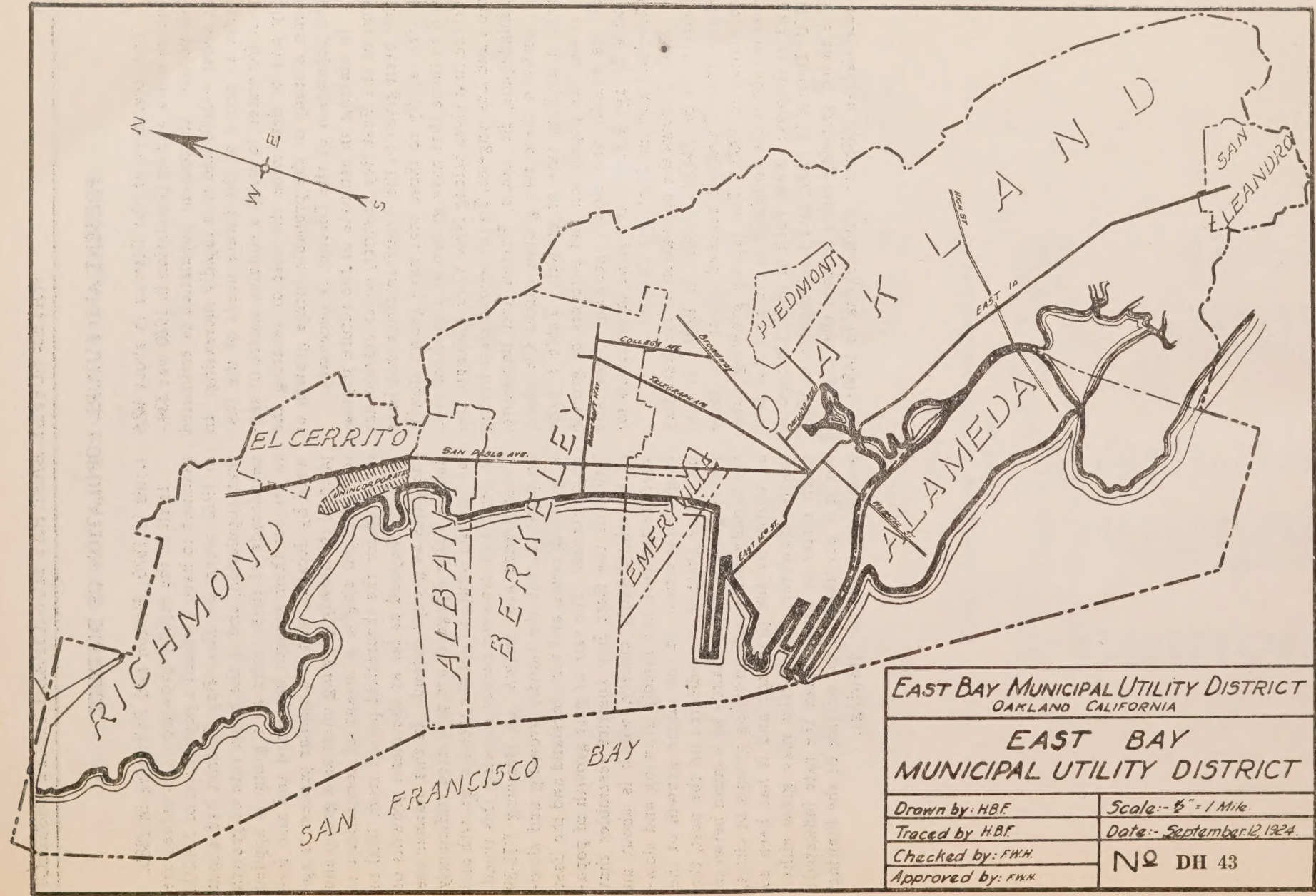
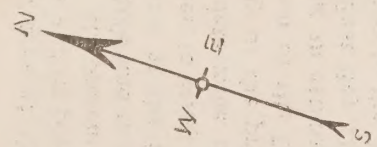
This is still further demonstrated by the action of many industries whose managers have investigated the water conditions in the District and have declined to invest. In case of a shortage it is obvious that domestic supply must be given the preference. Many industries have declined to locate in the District for these reasons, and some of the most important in this region have taken the precaution to provide their own water supplies in order to be certain of having sufficient water.

The refinery of the California Hawaii Sugar Company, said to be the largest in the world, undertook to supply its own needs for water by pumping its supply from Carquinez Strait above San Pablo Bay during the season of high water and by hauling it in barges from the Sacramento River during low water. However, the latter supply has failed, as the river water at the head of navigation is too salty for use in the refinery. The situation became so bad in 1920 that the company made a contract with the Marin District at San Rafael, under the terms of which the company built a wharf and long line of cast iron pipe to bring the water to the wharf, and pay \$31,000 per month for the privilege of hauling the water in barges from the wharf.

The Union Oil Company at Oleum obtains a large part of its water supply from Portland and Seattle in the form of ballast, and obtains an additional amount from wells of its own construction. Many other industries provide their own water supply from wells, and are suffering the jeopardy of saline invasion.

The disastrous Berkeley fire of September, 1923, owed its intensity and persistence in part to the inadequacy of the water distribution system.

Unless remedied, all of these conditions are, of course, not only serious to existing enterprises but disastrous to future growth. The investigations for an additional water supply from a distant source have, therefore, been conducted on the theory that the condition is urgent, that a water supply of acceptable purity and adequate quantity must be brought in with the utmost possible speed, and that time is of first importance. It has also been considered desirable to adopt a plan for furnishing an emergency supply of water before the major project can be completed.



EAST BAY MUNICIPAL UTILITY DISTRICT OAKLAND CALIFORNIA	
EAST BAY MUNICIPAL UTILITY DISTRICT	
Drawn by: H.B.F.	Scale: - 6" = 1 Mile.
Traced by: H.B.F.	Date: - September 12, 1924.
Checked by: F.W.H.	No DH 43
Approved by: F.W.H.	

PRESENT AND FUTURE POPULATION OF DISTRICT

The total area of the District is about 92.6 square miles, and its population in 1920 was 334,348 people. Its present population is estimated at about 440,000 and it is rapidly increasing. In order to arrive at the future needs of the District for water, to select a suitable source of supply and to determine the cost of securing the same, a study of the probable future growth of the population of the District is necessary.

In making an estimate of the future population of the East Bay District, consideration has first been given to the American cities that have grown rapidly to those that have grown slowly, and to those that have grown at a medium rate. To the first class belong New York, Chicago, Detroit and Los Angeles. To the second class belong Philadelphia, St. Louis, Boston and Baltimore. In between these two groups comes Cleveland, with a medium rate of growth. Table 1, page 9 shows the population and percents of growth of the rapidly and slowly growing cities, and Table 2, page 9 shows the same information for Cleveland and the East Bay District.

Table 3 shows the population of the East Bay District to be 334,348 people in 1920. It also shows that Cleveland reached about the same population in 1900. The rapidly growing cities reached about the same size as the East Bay District as follows: New York in 1840; Chicago in 1870; Detroit in 1900; and Los Angeles in 1910. The slowly growing cities reached that approximate size as follows: Philadelphia in 1850; St.

Louis in 1870; Boston and Baltimore in 1880.

If all of the rapidly growing cities named are assumed to have attained a population of 334,000 in 1920, when the East Bay District had about that population, and if the mean rate of growth per decade of these cities as a group is applied to project their growth backward and also forward by decades, and if a similar process is applied to the slowly growing cities as a group and to Cleveland singly, a means of comparison is obtained for the theoretical period from 1860 to 1920 and beyond as far as the mean growths of the cities as groups extend. In this manner the data in Table 3 page 10 are projected sufficiently far into the future to get the trend of growth and to permit of drawing curves showing this trend. These trends are shown on Drawing DH-39 on page 11., for the rapidly growing and slowly growing cities, and for Cleveland and the East Bay District. The rate of past growth of population of the East Bay District resembles that of Cleveland fairly closely, which is about an average between the rapidly growing and slowly growing cities. If the future growth of the East Bay District is predicated on the past, the future growth may be taken as a mean between the rapidly and slowly growing groups of cities, as shown by the drawing; and it has been so taken. However, the District may grow either much faster or slower than the rate indicated; but it is not likely to go outside of the limiting groups given on the drawings.

TABLE 1
RATE OF GROWTH OF RAPIDLY AND SLOWLY GROWING CITIES
Rapidly Growing Cities

NEW YORK			CHICAGO		DETROIT		LOS ANGELES	
Year	Popula- tion	Per Cent Inc.	Popula- tion	Per Cent Inc.	Popula- tion	Per Cent Inc.	Popula- tion	Per Cent Inc.
1790	49,401							
1800	79,216	60.4						
1810	119,734	51.0						
1820	152,056	27.1			1,422			
1830	242,278	59.3			2,222	56.2		
1840	391,114	61.5	4,470		9,102	310.0		
1850	696,115	78.1	29,963	570.3	21,019	130.6	1,610	
1860	1,174,779	68.7	109,260	264.6	45,619	117.2	4,385	172.0
1870	1,478,103	25.8	298,977	173.6	79,577	74.4	5,728	30.8
1880	1,911,698	28.4	503,185	68.3	116,340	46.0	11,183	95.3
1890	2,507,414	31.3	1,099,850	118.6	205,876	77.0	50,395	351.0
1900	3,437,202	37.2	1,698,575	54.3	285,704	38.7	102,479	104.0
1910	4,766,883	38.9	2,185,283	28.8	465,766	63.5	319,198	211.0
1920	5,620,048	17.7	2,701,705	23.6	993,678	113.0	576,673	81.0

Slowly Growing Cities

PHILADELPHIA			ST. LOUIS		BOSTON		BALTIMORE	
Year	Popula- tion	Per Cent Inc.	Popula- tion	Per Cent Inc.	Popula- tion	Per Cent Inc.	Popula- tion	Per Cent Inc.
1790	28,522				18,320		13,503	
1800	41,220	44.7			24,937	35.9	26,514	96.3
1810	53,722	30.4			33,787	35.7	46,555	75.7
1820	88,000	64.0			43,298	28.2	62,738	34.7
1830	141,000	60.0			61,392	41.8	80,620	28.6
1840	225,927	60.0	16,469		93,383	52.2	102,313	27.0
1850	338,832	50.0	77,860	372.5	136,881	46.5	169,054	65.3
1860	565,529	63.8	160,773	116.6	177,840	30.0	212,418	25.9
1870	674,022	19.2	310,864	93.5	250,526	41.0	267,354	25.9
1880	847,170	25.7	350,518	12.8	362,839	44.8	332,313	24.3
1890	1,046,964	23.5	451,770	29.0	448,477	23.5	434,439	30.7
1900	1,293,697	23.8	575,238	27.2	560,892	25.4	508,957	17.4
1910	1,549,008	19.7	687,029	19.3	670,585	19.4	558,485	9.8
1920	1,823,779	17.7	772,897	12.5	748,060	11.5	773,826	31.4

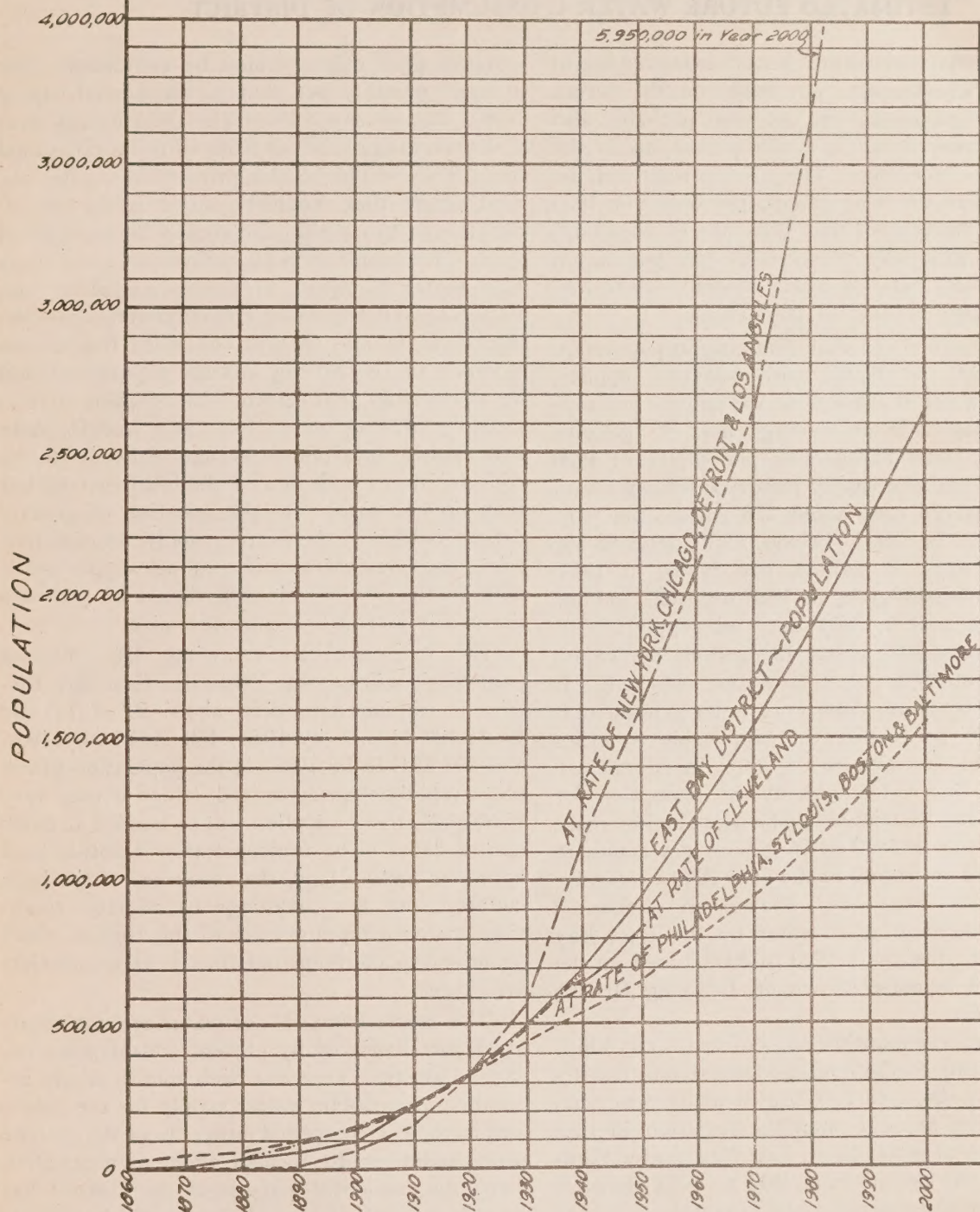
TABLE 2
**Rate of Growth of Cleveland and East Bay
District**

CLEVELAND			EAST BAY DISTRICT	
Year	Population	Per Cent Increase	Population	Per Cent Increase
1820	606			
1830	1,076	77.5		
1840	6,071	465.0		
1850	17,034	180.2		
1860	43,417	155.0	2,003	
1870	92,829	114.0	12,057	502.0
1880	160,146	72.3	40,263	234.4
1890	261,353	63.3	65,176	62.2
1900	381,768	46.2	99,907	53.2
1910	560,663	47.0	229,404	129.6
1920	769,841	42.2	334,348	45.7

TABLE 3
Estimated Rate of Growth of Population of the East Bay District

Year	East Bay District Past and Estimated Future Growth		Growth at Rate of New York, Chicago, Detroit, and Los Angeles		Growth at Rate of Philadelphia, St. Louis, Boston, and Baltimore		Growth at Rate of Cleveland	
	Popu- lation	Percent Increase	Popu- lation	Percent Increase	Popu- lation	Percent Increase	Popu- lation	Percent Increase
1860	2,003		2,600		32,500		5,300	
1870	12,057	502.0	6,500	151.3	45,000	38.4	15,000	180.2
1880	40,263	234.4	11,000	69.5	62,000	36.5	38,000	155.0
1890	65,176	62.2	19,000	73.6	98,000	58.9	81,000	114.0
1900	99,907	53.2	67,000	248.6	135,000	38.6	140,000	72.3
1910	229,404	129.6	151,000	126.2	218,000	60.9	228,000	63.3
1920	334,348	45.7	334,000	121.2	334,000	53.2	334,000	46.2
1930	501,000	50.0	577,000	72.7	443,000	32.7	491,000	47.0
1940	702,000	40.0	1,155,000	100.1	544,000	22.8	699,000	42.2
1950	948,000	35.0	1,620,000	40.0	655,000	20.5	944,000	35.0
1960	1,230,000	30.0	2,080,000	28.6	796,000	21.4	1,230,000	30.0
1970	1,540,000	25.0	2,650,000	27.4	941,000	18.2	1,530,000	25.0
1980	1,880,000	22.0	3,640,000	37.2	1,130,000	19.7	1,870,000	22.0
1990	2,260,000	20.0	5,050,000	38.9	1,330,000	17.7	2,240,000	20.0
2000	2,660,000	18.0	5,950,000	17.7	1,550,000	16.8	2,650,000	18.0

ESTIMATED FUTURE POPULATION EAST BAY DISTRICT



EAST BAY MUNICIPAL UTILITY DISTRICT
OAKLAND CALIFORNIA

ESTIMATED FUTURE POPULATION OF EAST BAY DISTRICT

Drawn by: H.B.F.

Scale: None.

Traced by: H.B.F.

Date: September 3, 1924

Checked by:

NO DH 39

Approved by:

ESTIMATED FUTURE WATER CONSUMPTION OF DISTRICT

The estimated future water consumption of the District depends not only on the future growth of its population, but most probably also on an increased use of water per capita as the population increases. The use of water in the District was about 85 gallons per capita in 1920 and it is anticipated that this rate of consumption will gradually increase as the population grows, since this is a usual incident in the history of large centers of population.

A study of seven cities ranging in population from 50,000 to 430,000, with metered supplies, indicates a use of from 57 to 132 gallons per capita per day with an average near 95 gallons. Baltimore used 129 gallons per capita in 1920 with 11.3% of the supply metered; Chicago with 27.5% metered used about 275 gallons per capita per day in 1923. Toledo, Ohio, with 98.3% metered, used 85 gallons per capita in 1923. Spokane, Washington, in 1923 used 227 gallons per capita with a fully metered supply. New York used in 1923 about 129 gallons per capita with about 27% of the water metered. It appears, therefore, that there is no general uniformity in per capita use, applicable to cities as a whole, or cities as a group. It is believed, however, that a fair and liberal assumption for the East Bay District would be a gradual increase from the use in 1920 of 85 gallons per capita to 125 gallons per capita in the year 2000. Drawing DH-40, on page 14, shows an estimated future consumption of water by the East Bay District for the years 1920 to 2000, based on the population increase shown on Drawing DH 39, on page 11.

The average monthly rates of water consumption in terms of the average annual rate usually vary from about 85 to 120% in many American cities. The average monthly variation in rate of delivery of water by the East Bay Water Company for the period from 1915 to 1923 inclusive in terms of the average annual monthly rate is as follows: Jan. 85.4%; Feb. 84.8%; March 86.0%; April. 96.3%; May 104.6%; June 113.6%; July 114.6%; August 115.5%; Sept. 111.6%; October 100.6%; Nov. 96.3%; and Dec. 90.1%. The per cents of the annual use that these monthly uses work out to be are as follows: Jan. 7.3%; Feb. 6.5%; March 7.3%; April 7.9%; May 8.9%; June 9.3%; July 9.7%; August 9.8%; September 9.2%; October 8.5%; November 7.9%; and December 7.7%. From these percentages, the

summer peak delivery may be estimated. The average monthly per cent of the annual supply is 8 1-3%, or say 8.3%. The total excess over this percentage is about 5.6% of the total annual use. This would be the proportion of the annual supply that should be cared for by the local storage to equalize the annual fluctuations in use. The monthly peak delivery in the East Bay Water Company service is somewhat less than that in many cities, the maximum often being about double that in the East Bay Cities. Whence the equalizing storage capacity should be more than that given. In addition to this monthly peak delivery, there is a weekly, daily and hourly maximum average delivery to be considered in the design of the local system, but they do not enter into the question of general determination of the water supply for the District. Any variation in the annual supply available, in the source selected, should be provided for in the local storage system also.

By reference to Drawing DH 40, on page 11, it will be noted that the East Bay District is estimated to need about 50 M.G.D. by 1932; 100 M.G.D. by 1952; 150 M.G.D. by 1966, and 200 M.G.D. by 1977. If the population grows more rapidly than estimated, which it may very readily do, these supplies will be needed at much earlier dates. The transportation facilities, both by water and by land, the resources of the back country, and the advantageous climatic conditions assure a rapid growth of this region, which promises to continue indefinitely at an accelerated rate.

The future demands for water are not accurately foreshadowed by present consumption because industries have not been able to secure assurance of abundant water supply for the future and have been compelled either to locate at some other point or to furnish their own supplies. Thus the industrial growth of the District has been hampered, and it is believed will be greatly accelerated by the assurance of an ample future water supply. It is desirable that such assurance be given as soon as possible and confirmed by quick construction. How large this supply should be is a question which involves not only the present needs and the probable future growth, but also the availability of the necessary water supply at a point near enough and cheap enough to permit the District, with its present resources, to obtain that supply.

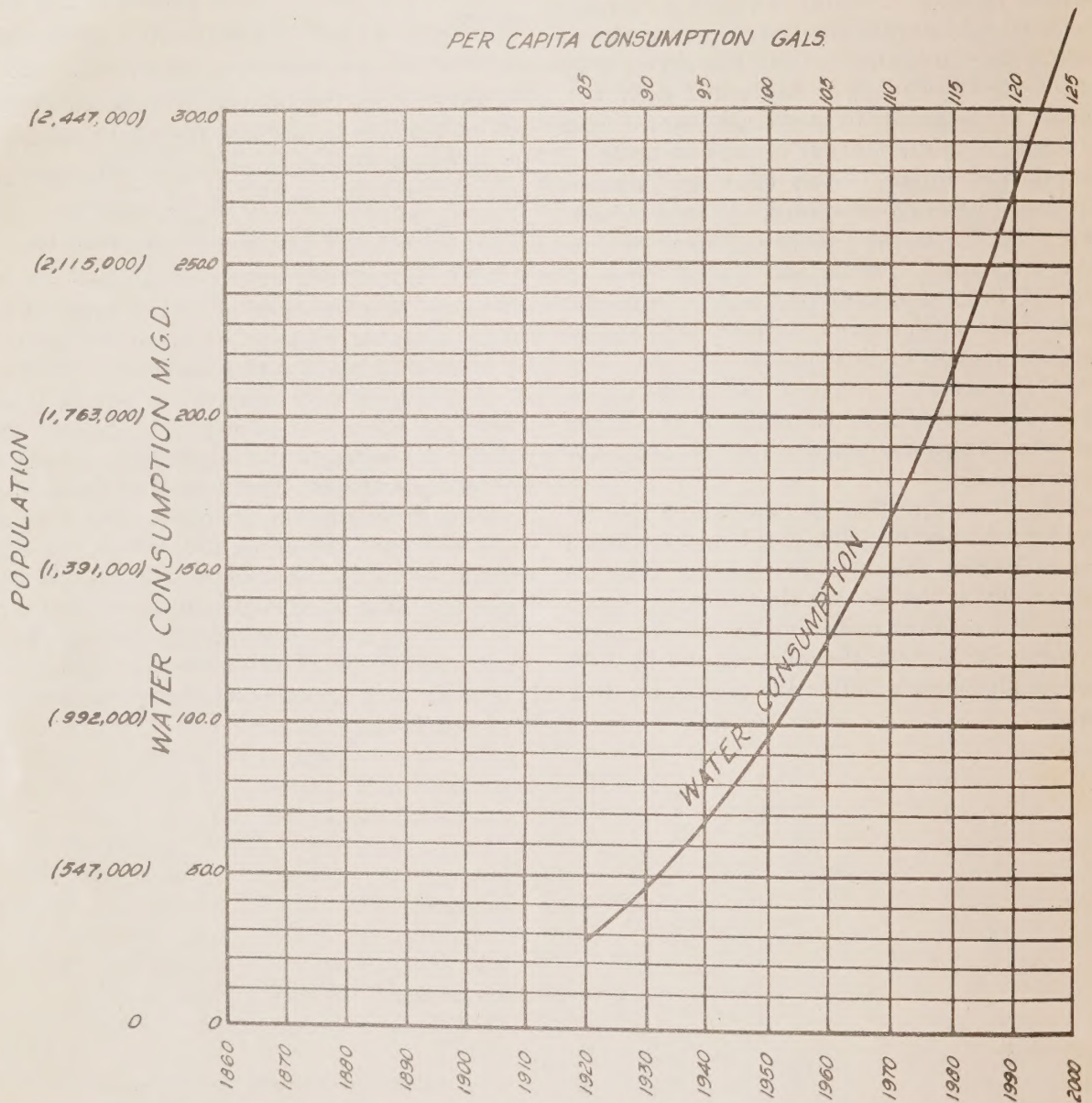
Many of the industries of the East Bay Region have provided their own water supply by pumping, and are desirous of getting their water from the District. A large delegation recently attended the meeting of the Board of Directors of the East Bay Municipal Utility District to urge the consideration of their needs and their willingness to co-operate by purchasing water from the supply that the District intends to bring in. The principal towns in this class are Antioch, Martinez, Pittsburg, Concord, Walnut Creek, Pinole, Bay Point and Crockett. North of Carquinez Strait are Benicia and Vallejo, both of which are in need of additional water. Mare Island is also a prospective customer. The aggregate consumption of this outside region is over 11 M.G.D., and it is believed that those towns will readily double their consumption in a short time after additional pure water becomes available.

It seems certain that the growth of the demand for water in this District is bound to exceed at an early date the possibility of providing an ample supply at the present time to meet it, and the problem resolves itself into one of obtaining the purest, the largest, the quickest, and the best water supply possible within the present bonding limit.

The assessed valuation of this District is about \$324,000,000. The law limits the bonding capacity to 20% of the assessed valuation, and \$64,000,000 may be taken as the limit of funds which can be made available by a two-third's vote of the people. Of this amount, perhaps \$25,000,000 will be required to purchase the local system and to introduce improvements, renewals, and extensions that are greatly needed therein. This leaves \$39,000,000 as the amount available for developing a distant water supply, and the requirement may be stated as that of bringing the largest quantity of pure water to this District that can be obtained within that limit. Obviously, it is desirable to adopt some source which will be capable of large expansion beyond that possible with the present expenditures, and this has been given a prominent place in the studies.

It has been assumed, therefore, that a supply from a distant source of 250 M.G.D., or even more, is desirable, but with present financial limitations, it may be necessary to be content with 200 M.G.D., a part of which can be brought in quickly with present resources, and which will be capable of large economical expansion as the need arises.

ESTIMATED FUTURE WATER CONSUMPTION EAST BAY DISTRICT



EAST BAY MUNICIPAL UTILITY DISTRICT
OAKLAND - CALIFORNIA

ESTIMATED FUTURE
WATER CONSUMPTION
FOR
EAST BAY DISTRICT

Drawn by: H.B.F.

Scale: None

Traced by: H.B.F.

Date: September 4, 1924

Checked by: F.W.H.

Approved by: F.W.H.

Nº DH 40

AVAILABLE LOCAL WATER SUPPLIES

A study has been made of the run-off and storage facilities available from San Leandro, San Pablo, Wildcat, and Pinole Creeks. All of these creeks are now being used as a part of the water supply of the towns in the East Bay District except Pinole, and a reservoir site has been located on this creek, and a study made of the possible utilization of it in the development of the water supply for the East Bay District. In this study, the figures compiled by the East Bay Water Problem Committee in its report of February 12, 1923, to the Oakland Chamber of Commerce, have been used in part.

The run-off of San Leandro Creek can be conserved in what are known as Upper San Leandro and Lake Chabot reservoirs; that of Wildcat Creek and San Pablo Creek can be conserved in the San Pablo reservoir; and that of Pinole Creek can be conserved in Pinole reservoir. Lake Chabot and San Pablo reservoirs are now completed and in use. Upper San Leandro Reservoir is under construction. These reservoirs are the property of the East Bay Water Company. The Pinole Reservoir is here considered only as a possible extension of the local system. The storage capacities of these four reservoirs in the creeks named, and the drainage areas in these creeks above the reservoirs, are as follows:

Name of Reservoir	Flow Line Elevation	Capacity in Acre Feet	Drainage Area in Sq. Mi.
Upper San Leandro	460	50,250	30.30
Lake Chabot	235	15,100	11.75
San Pablo	315	43,193	35.25
Upped Pinole	315	30,235	10.50
Total		138,778	87.80

It will be noted that the total storage capacity in these reservoirs is 138,778 acre feet, and that the drainage area leading into them is about 88 square miles. One page 17 is a map designated DH 41 showing the location of the streams and reservoirs referred to.

The run-off from the creeks here considered has been studied by various authorities in the past and a re-estimate has been made in this study which agrees fairly closely with the quantities heretofore estimated. The estimated safe yield is approximately 27 M.G.D.

There is available a record for the flow on San Leandro Creek, kept by the East Bay Water Company since 1886-7 down to the present time, and there is also a record kept by it for the flow

of San Pablo Creek since 1906-7. From the simultaneous records of San Pablo Creek and San Leandro Creek during the last eleven years a percentage of relation of annual flow between them has been established. These records indicate that the mean flow of San Pablo Creek in terms of that of San Leandro Creek, for the 11 year period considered, is 94%. During the years in which there are no measurements of the flow of San Pablo Creek, it is assumed to be 94% of that of San Leandro Creek. The run-off's per square mile of Wildcat and Pinole Creeks are also assumed to be the same as that from San Pablo Creek, since the drainage areas are quite similar and adjacent.

As a means of obtaining the effect of evaporation on the water supply, without making the laborious computations necessary in applying monthly evaporations to reservoir stages, the following percentages of the drafts from the reservoirs have been adopted:

Upper San Leandro	9.2 per cent
Lake Chabot	13.0 per cent
San Pablo	9.4 per cent
Upper Pinole	9.2 per cent

Based on the reservoir capacities, the drainage areas leading into the reservoirs, the run-off relations and evaporation losses already stated, computations of the yields of the drainage areas and reservoir yields have been made.

These computations indicate a safe net yield of 10.1 M.G.D. for Upper San Leandro; 3.35 M.G.D. for Lake Chabot; 9.7 M.G.D. for San Pablo-Wildcat and 3.9 M.G.D. for Pinole. The years 1897-8; 1911-12; 1912-13; 1920-21 and 1923-24 all show exceptionally low yields, that for 1923-24 being the worst of all. In this year the run-off is only about 5% of the mean run-off from the various watersheds for the period of 38 years under consideration and the reserve available in the reservoir is remarkably low. Unless, therefore, 1924-25 should be a year of good run-off, the safe net yield of the drainage areas considered would be greatly reduced.

In the computation relating to San Pablo Reservoir, it has been assumed that all of the flow from Wildcat Creek can be diverted into the San Pablo reservoir through the existing diversion canal and tunnel having a capacity of 250 second feet, the diversion dam on Wildcat Creek being capable of storing 28 acre feet. The drainage area of Wildcat Creek above the diversion

dam is quite small being only 3.1 square miles. It is, therefore, assumed that occasions will be very rare when all of the waters of Wildcat Creek cannot be diverted into San Pablo Creek. Moreover, the time when these occasions arise would be likely to be in the years when San Pablo Reservoir was full from run-off from San Pablo Creek.

In the computation and tabulation made for the Pinole Reservoir, it will be observed that, since the reservoir is very large in proportion to the run-off of the stream, no water would ever be wasted from the reservoir.

Of the water supply sources here considered, the San Leandro and San Pablo-Wildcat streams and reservoirs on them, owned by the East Bay Water Company, have an estimated safe net yield of 23 M.G.D. In addition to these sources, the company claims yields from the Temescal watershed of 0.3 M.G.D., from tunnels and springs 0.5 M.G.D., and from wells 16.5 M.G.D. Of this latter amount the company considers 11 M.G.D. as normal draft, and 5.5 M.G.D. as reserve draft. This would give a total normal draft of 34.8 M. G.D. and a total draft, including reserve, of 40.3 M.G.D. The capacities of the wells of the company are as follows:

Alvarado	8.0 M.G.D.
San Lorenzo	5.0 M.G.D.
92nd Avenue	0.5 M.G.D.
Union Water Company	2.0 M.G.D.
Fitchburg	1.0 M.G.D.

TOTAL16.5 M.G.D.

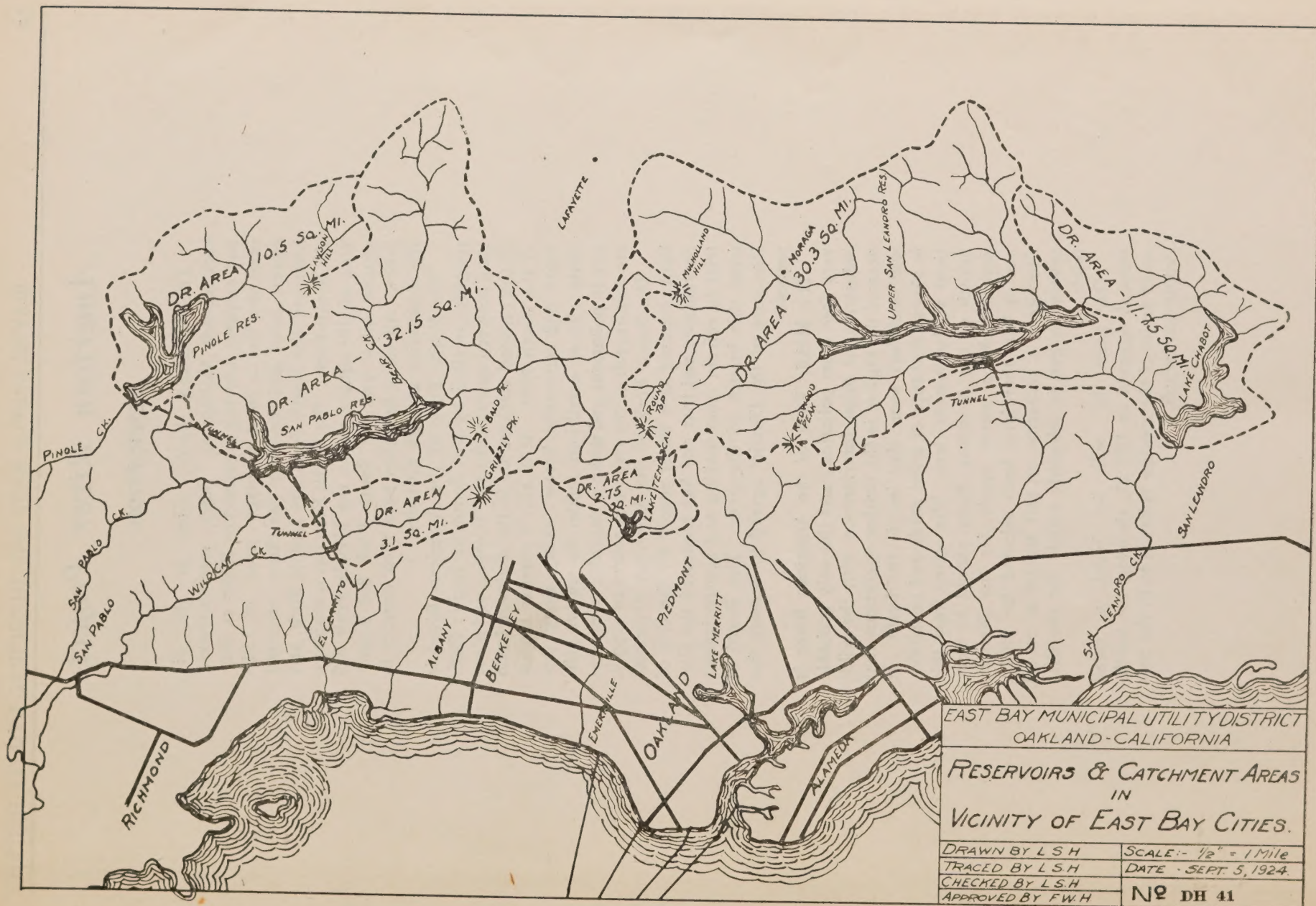
The supply from wells is not suitable for general manufacturing purposes and is badly needed for irrigation purposes. If this supply is eliminated, the amount available is then about 23.8 M.G.D., from the San Leandro and San Pablo-Wildcat watersheds. To this may be added about 4 M.G.D. for Pinole Creek development, making a total of about 28 M. G. D. as the safe net yield to the East Bay District from local sources.

Since it is very evident that at least 50 M. G.D. will be needed at least within the next 8 years; and since there are available only about 28 M.G.D. from all desirable local sources; since all reserve supplies are now nearly exhausted; and since a much more abundant general supply is now urgently needed; it is clear that provision should be made to bring into the district at least 50 M.G.D. at the earliest practicable date from some suitable distant source.

SOURCE OF DISTANT SUPPLY

The sources of water available for an increased supply for the East Bay District are numerous, but all are distant and expensive of development. Some of them are also complicated with prior rights to use of the water, or are not otherwise suitable for use. Various sources have been suggested by interested parties. Some of these sources have been quite readily eliminated on account of their comparative unavailability for a water supply for the District. Of the sources thus rejected are the Stanislaus, Feather, and McCloud rivers. The Stanislaus river has very little summer run-off, and this is entirely used for irrigation. The irrigated lands are moreover in need of additional water to supplement the summer flow, and it is proposed by the interested parties to construct a high storage

dam on the Stanislaus River to provide this supply. These conditions, together with the great distance of the source, make this river a comparatively unfavorable source of water supply for the District. The Feather River has been discarded for the same reasons. The great distance to the McCloud River makes an aqueduct therefrom too expensive for present consideration, and this has been considered sufficient grounds for its elimination. Thus the studies have been narrowed down to the American, Eel, Mokelumne, Sacramento, and Tuolumne rivers. The results of the investigation of these sources will be discussed under headings bearing the names of these rivers. A map designated as DH 30, showing the general schemes involved in these projects, follows page 17.



American River Project

DESCRIPTION

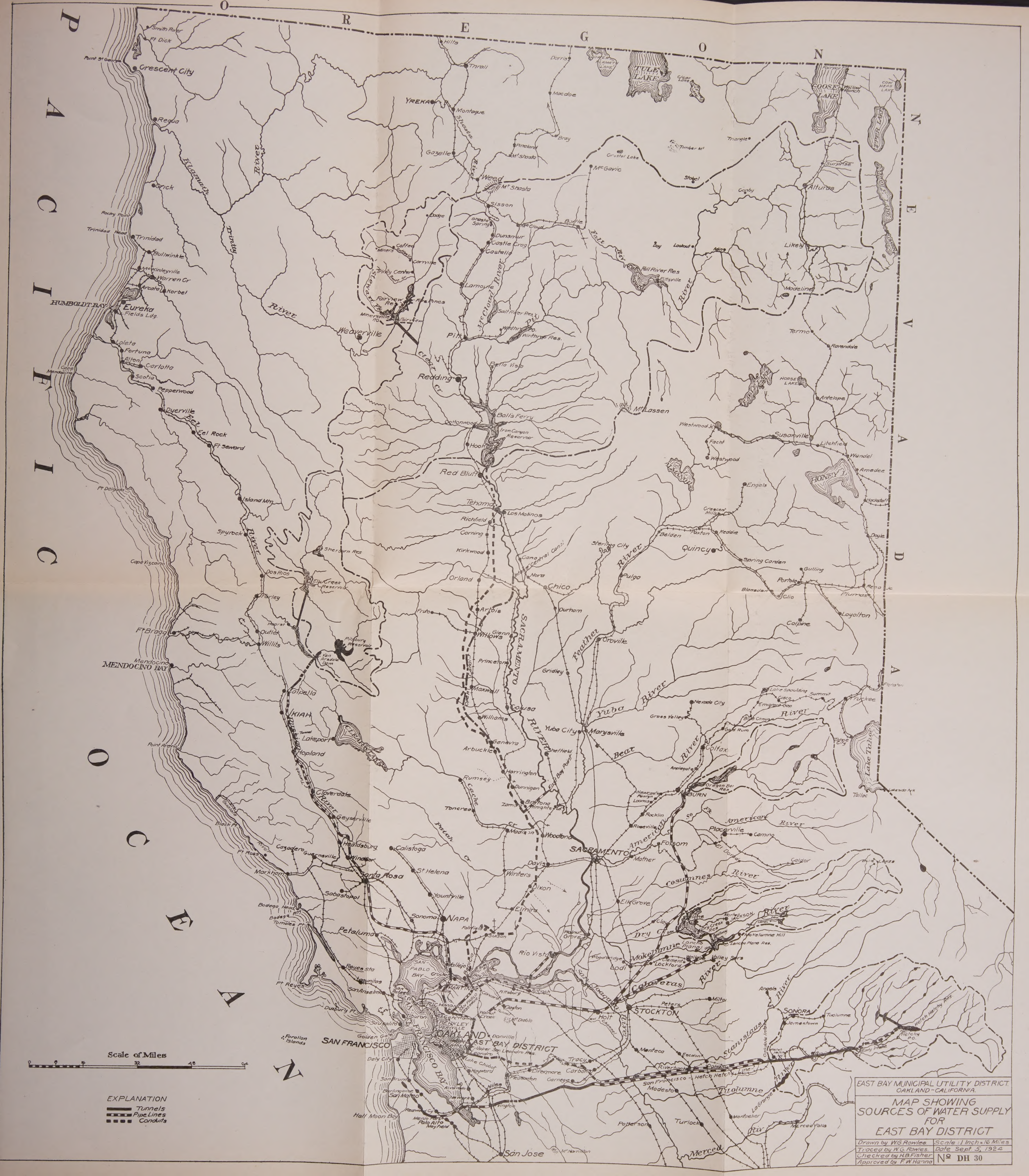
The American River, rises in the Sierra-Nevada Mountains, flows southeastward and empties into the Sacramento River at Sacramento, has a total drainage area of 1,919 square miles and the river has three principal branches, the North Fork, the Middle Fork, and the South Fork. The North Fork has a drainage area of 349 square miles, the Middle Fork 619 square miles, and the South Fork 862 square miles. All three branches have their sources in the mountains at high altitudes.

The North Fork of the American River is roughly paralleled by the Southern Pacific Railroad between Sacramento and Truckee, and some of the railroad stations are in the drainage basin of the North Fork. It is also a popular tourist route and numerous hotels exist along this route. These conditions render its waters subject to pollutions and make it desirable to eliminate this branch of the river as a source of supply.

The South Fork of the American River has been proposed as a water supply for the City of Sacramento and that city has requested the District to refrain from making any appropriations from this branch of the river. The Board of Directors of the District agreed to respect this request.

The Middle Fork of the American River is very free from pollution; and the only probable industries, or other interference with the wildness of the region, is the lumber operations that will doubtless some day invade the basin. It is almost destitute of good roads and of habitations at the present time. The water from this branch of the American River should be very desirable for a water supply for the District, and it has, therefore, been selected for study. Storage is a necessity, on this stream as on all others, to get an adequate supply for the District.

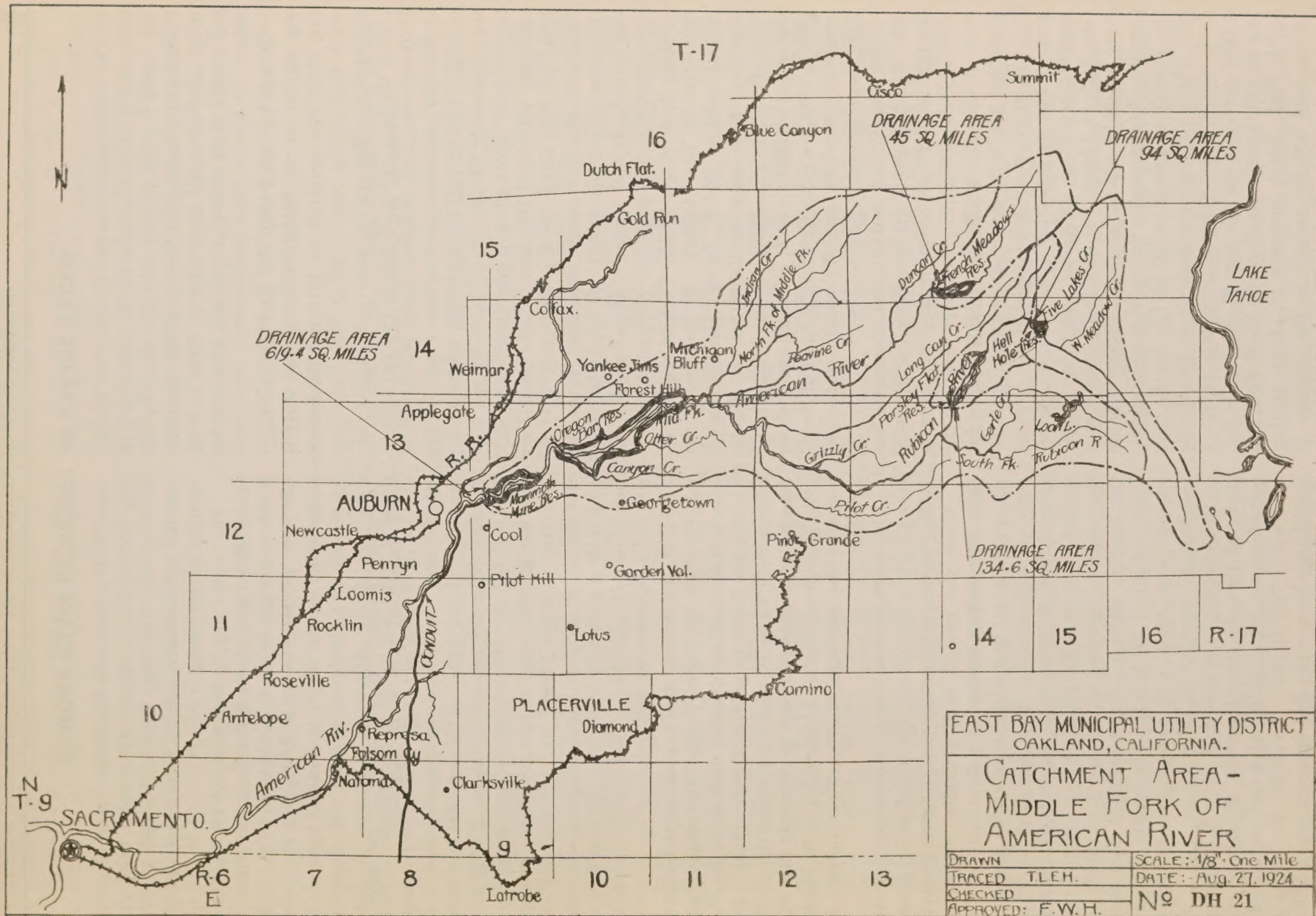
On page 19, will be found a small map, designated as DH 21, showing the catchment areas of the storage referred to in the preceding paragraph.



Scale of Miles

EXPLANATION
Tunnels
Pipe Lines
Conduits

EAST BAY MUNICIPAL UTILITY DISTRICT,
OAKLAND-CALIFORNIA.
MAP SHOWING
SOURCES OF WATER SUPPLY
FOR
EAST BAY DISTRICT
Drawn by W.G. Rowles
Traced by W.G. Rowles
Checked by H.B. Fisher
Approved by F.W. Hanna
Scale: 1 Inch = 16 Miles
Date: Sept. 5, 1924
No. DH 30



EAST BAY MUNICIPAL UTILITY DISTRICT
OAKLAND, CALIFORNIA.

CATCHMENT AREA - MIDDLE FORK OF AMERICAN RIVER

DRAWN	SCALE: 1/8" = One Mile
TRACED T.L.E.H.	DATE: Aug. 27, 1924
CHECKED	
APPROVED: F.W.H.	No DH 21

WATER SUPPLY OF AMERICAN RIVER PROJECT

The water measurements of value for the determination of the question of the sufficiency of the supply for this project are those made by the United States Geological Survey on the American River at Fair Oaks from 1904 to 1924, and on the Middle Fork near East Auburn from 1911 to 1924.

It will be noted that the East Auburn Gaging station on the Middle Fork of the American River was operated for 1911 and thereafter, while that on the main river at Fair Oaks was operated for 1904 and thereafter. In order to arrive at the flow of the Middle Fork from 1904 to 1910 inclusive, a comparison of the monthly flow at the two points in question was made for the period of 1911 to 1923 during which both stations were operated. Messrs. Hyde, Wilhelm and Miller, in their report on a Water Supply for Sacramento, estimated the flow of the American River at Fair Oaks for a period from 1895 to 1900 from the flow of the Stanislaus River for the same period based on U. S. Geological Survey records on that stream. These figures have been adopted in this study and reduced to corresponding flow for the Middle Fork of the American River at East Auburn as they cover the critical period of 1897-8. In this manner run-off data have been made available for the Middle Fork of the American River at East Auburn for the period of 1895 to 1924, of which those from 1895 to 1910 are estimated on the basis of measurements elsewhere and the balance taken directly from stream gaging records.

The Pacific Gas and Electric Company has prior rights on the American River water supply for 1250 second feet, which it uses in its power plant at Folsom, dumping the water back into the river at this point. This water is available for irrigation use in the lower American River Valley, and much more than supplies the present prior rights for irrigation. As to future, developments requiring additional water for irrigation, little is known, but this study shows that there would be a large amount of water wasted annually after supplying the existing prior rights, and furnishing a draft of 200 M.G.D. for the East Bay District, the annual waste from the Middle Fork above East Auburn averaging nearly a million acre-feet for the last 30 years. To this may be added the waste from the North Fork and South Fork, which amounts to about another million acre-feet per annum on the average. It appears, therefore, that there should be ample

water in the American River watershed, if properly conserved, to supply the present uses, the needs of the East Bay District for 200 M.G.D. and the requirements for all future probable irrigation development.

The water supply development on the American River proposed for the East Bay District involves storage on the lower stretch of the Middle Fork of the American River, and the point of diversion for the supply is assumed to be made by means of a combined storage and diversion dam just above Mountain Quarries a short distance above the mouth of the stream. A dam at this point, 200 feet high, will provide about 100,000 acre feet of storage capacity and it is possible to build a dam at this site 300 feet high, giving a reservoir capacity of about 235,000 acre feet. From the United States Geological Survey topographic maps it appears that a storage reservoir of about 280,000 acre-feet capacity exists at a short distance above the proposed point of diversion with a dam of about 350 foot height just above Oregon Bar. There is an excellent site for a high dam at this point.

For the location of the Oregon Bar and Mountain Quarries reservoirs, rainfall and evaporation data will be quite comparable with those for the Mokelumne River project at Lancha Plana. By reference to Table 10 of the report on the Mokelumne River project, it will be observed that the estimated gross annual evaporation is 56 inches and that the net value corrected for rainfall is 32 inches.

The average annual evaporation loss on the Lancha Plana Reservoir was found to be about 5,000 acre-feet in the study made of that project.

From the run-off data available, estimates have been made, on a monthly flow basis, of the amount of water needed for prior rights, the amount available for the East Bay District from natural flow, the amount of water available and needed for storage for the East Bay District and the amount of surplus or deficiency of supply in the stream; all based on an assumed East Bay District draft of 200 M.G.D. The results of these computations have been summarized by years and brought together in Table 4.

On referring to column 9 of Table 4, it will be observed that the annual amount of storage required varies from 56,100 acre-feet to 217,600 acre-feet. The largest demands for storage would have been in the hydrographic years 1897-1898 and 1910-11 and 1918-19 and 1923-24. It ap-

pears that a reservoir at Oregon Bar, with a capacity of 217,600 acre-feet, plus sufficient to care for evaporation, would have provided an adequate supply for the East Bay District for conditions as they have existed for the past 30 years. A reservoir with 225,000 acre-feet capacity would have met the demand fully and have cared for evaporation also.

Attention is directed to the large amount of waste from the Middle Fork of the river nearly every year, amounting on the average to 984,-

016 acre feet. The wastes in 1897-8 and in 1923-4 are, however, very small; and indicate that carry-over storage would be needed in case of a diversion for the East Bay District of more than 200 M.G.D.] In column 10 of Table 4 are given the dates on which the maximum accumulated drafts would occur, the reservoir being filled during the flood season each year. The maximum accumulated draft would of course be the amount of storage to carry the project over to the next flood season.

TABLE 4

Summary of Water Supply Computations for a Draft of 200 M. G. D. from Middle Fork of the American River Near Its Mouth Supplemented with the Oregon Bar Reservoir

1	2	3	4	5	6	7	8	9	10	11
Hydro- graphic Year Oct.-Sept.	Run-off at Fair Oaks Acres Feet	Prior Rights P. G. & E. Co. at Folsom Acres-Ft.	Water Available at Fair Oaks for Diversion Acres Feet	Run-off of Middle Fork Near E. Auburn Acres Feet	Estimated Flow Available East Bay District at Middle Fork Acres Feet	Draft for East Bay District From Natural Flow Acres Feet	Draft for East Bay District From Storage Acres Feet	Maximum Draft From Reservoir During Cycle Acres Feet	Date of Maximum Accumulated Draft in Year	Water Wasted on Middle Fork Acres Feet
1896-96	3,148,000	704,100	2,443,900	1,416,940	1,336,200	130,900	93,500	56,100	Oct., 1896	1,093,100
96-97	3,392,000	718,300	2,673,700	1,533,410	1,484,900	149,600	74,800	108,200	Feb., 1898	1,279,200
97-98	1,039,000	613,500	425,500	472,140	325,800	94,400	130,000	126,300	Dec., 1898	115,500
98-99	2,333,000	601,600	1,731,400	1,069,890	983,200	103,800	120,600	74,800	Oct., 1899	744,700
99-00	2,576,000	674,800	2,901,000	1,579,110	1,549,600	149,600	74,800	112,200	Dec., 1900	1,325,200
1904-05	2,003,010	677,410	1,325,600	897,920	805,200	122,200	112,200	112,200	Dec., 1905	580,800
05-06	4,761,740	651,540	4,110,200	2,156,180	2,095,000	130,900	93,500	74,800	Nov., 1906	1,851,900
06-07	5,710,400	778,800	4,931,600	2,532,840	2,464,800	166,400	58,000	58,000	Nov., 1907	2,223,600
07-08	1,453,620	692,420	761,200	650,950	565,100	130,900	93,500	112,200	Dec., 1908	376,200
08-09	4,544,600	667,400	3,877,200	1,965,080	1,905,800	130,900	93,500	56,100	Oct., 1909	1,662,700
09-10	3,542,200	691,400	2,850,800	1,561,910	1,523,600	149,600	74,800	93,500	Nov., 1910	1,317,000
1910-11	5,477,700	702,500	4,775,200	2,448,250	2,388,000	149,600	74,800	130,900	Feb., 1912	2,144,900
11-12	1,264,700	572,300	692,400	560,590	459,500	74,800	149,600	116,400	Feb., 1913	253,800
12-13	1,433,660	640,060	793,600	820,290	658,400	105,600	118,800	93,500	Nov., 1913	434,000
13-14	3,949,630	680,830	3,268,800	1,903,900	1,872,200	149,600	74,800	93,500	Dec., 1914	1,629,100
14-15	3,061,300	649,800	2,411,500	1,807,080	1,647,500	130,900	93,500	88,300	Dec., 1915	1,423,100
15-16	3,848,400	673,000	3,175,400	1,542,040	1,467,800	136,100	88,300	74,800	Nov., 1916	1,243,400
16-17	2,831,700	715,100	2,116,600	1,168,000	1,100,600	149,600	74,800	112,200	Jan., 1918	876,200
17-18	1,419,500	497,500	922,000	622,800	531,300	93,500	130,900	130,900	Jan., 1919	325,600
18-19	2,154,920	605,120	1,549,800	912,640	799,400	93,500	130,900	149,600	Feb., 1920	575,000
19-20	1,391,210	492,810	898,400	613,710	530,000	74,800	149,600	74,800	Oct., 1920	305,600
1920-21	3,224,200	750,600	2,473,600	1,262,670	1,210,100	150,400	74,000	92,700	Nov., 1921	984,900
21-22	3,349,300	712,100	2,637,200	1,280,110	1,239,600	149,600	74,800	74,800	Nov., 1922	997,300
22-23	2,750,200	739,200	2,011,000	1,136,000	1,061,100	149,600	74,800	112,200	Jan., 1924	836,700
23-24	594,400	494,100	100,300	242,000	100,300	54,500	169,900	217,600	Dec., 1924	0
Means	2,890,176	655,852	2,234,324	1,286,258	1,204,200	124,452	99,948			984,016

COST ESTIMATE FOR AMERICAN RIVER PROJECT

Estimates have been made of the probable cost of the development of the American River Project based on storage on the Middle Fork at the Oregon Bar Reservoir, diverting it at Mountain Quarries, and bringing it in an aqueduct from that point to local reservoirs. These estimates cover two plans, one in which it is proposed to bring in the water entirely by gravity flow, and another in which it is proposed to bring in the water by gravity as far as the base of the Coast Range and there raising it 150 feet and allowing it to flow by gravity into local reservoirs.

The estimates of costs are based on development in three units to meet the growing needs of

the population of the District. The first unit has a capacity of 50 M.G.D. and second and third units each 75 M.G.D., thus making the total ultimate development 200 M.G.D. These three units are assumed to be completed respectively in 1928, in 1941, and in 1974. For the purposes of comparison, the present worths of the estimated investments in the last two units are brought down from their mid-construction dates to that of the first unit, and the present worth of the whole development thus determined. The present worth of the estimated cost of the gravity project on this basis in 1926 is \$71,340,000 and that of the combined gravity and 150-foot pumping lift is \$66,585,000.

Eel River Project

DESCRIPTION

The Eel River rises on the western slope of the Coast Range and flows northwesterly into the Pacific Ocean about 10 miles south of Humboldt Bay. Its drainage area at Alton, near its mouth is 3547 square miles. This river has several important branches, the Van Duzen Fork with a drainage area of 440 square miles, the South Fork with a drainage area of 662 square miles, the North Fork with a drainage area of 284 square miles, the Middle Eel with a drainage area of 755 square miles, and the South Eel with a drainage area of 537 square miles. The portion of the stream with which this study is concerned is the Middle Eel and the South Eel.

The drainage areas of the Middle Eel River and South Eel River are situated on the western slope of the Coast Range and are almost completely uninhabited. The waters are, therefore, relatively free from human pollution, but the water from the existing reservoir on the South Eel appears to contain considerable vegetable matter and may require treatment to fit it for domestic use.

The Eel River has been, from time to time, suggested as a source of supply for the East Bay Cities by diverting and storing the head waters of the South Eel River and Middle Eel River through tunnels to the head waters of Russian River, and bringing them from that point in an aqueduct beneath Carquinez Strait to the Bay Region.

Development on the South Eel has already been accomplished by the Snow Mountain Water and Power Company, which has built a storage dam at Gravelly Valley, a diversion dam at Cape Horn, and a tunnel through the mountains into a small tributary of the East Fork of Russian River. Here power is developed and the water discharged into the Russian River drainage basin. The storage reservoir at Gravelly Valley, known as Pillsbury reservoir, has a capacity of 73,000 acre-feet at spillway elevation and a flashboard control of 10 additional feet, bringing the capacity up to 95,000 acre-feet. The diversion dam at Cape Horn is known as the Van Arsdale Dam. The company offers to sell its works to the East Bay Municipal Utility District.

From the tailrace of the Snow Mountain Water and Power Company's power plant it is possible to bring the water, through tunnels and other

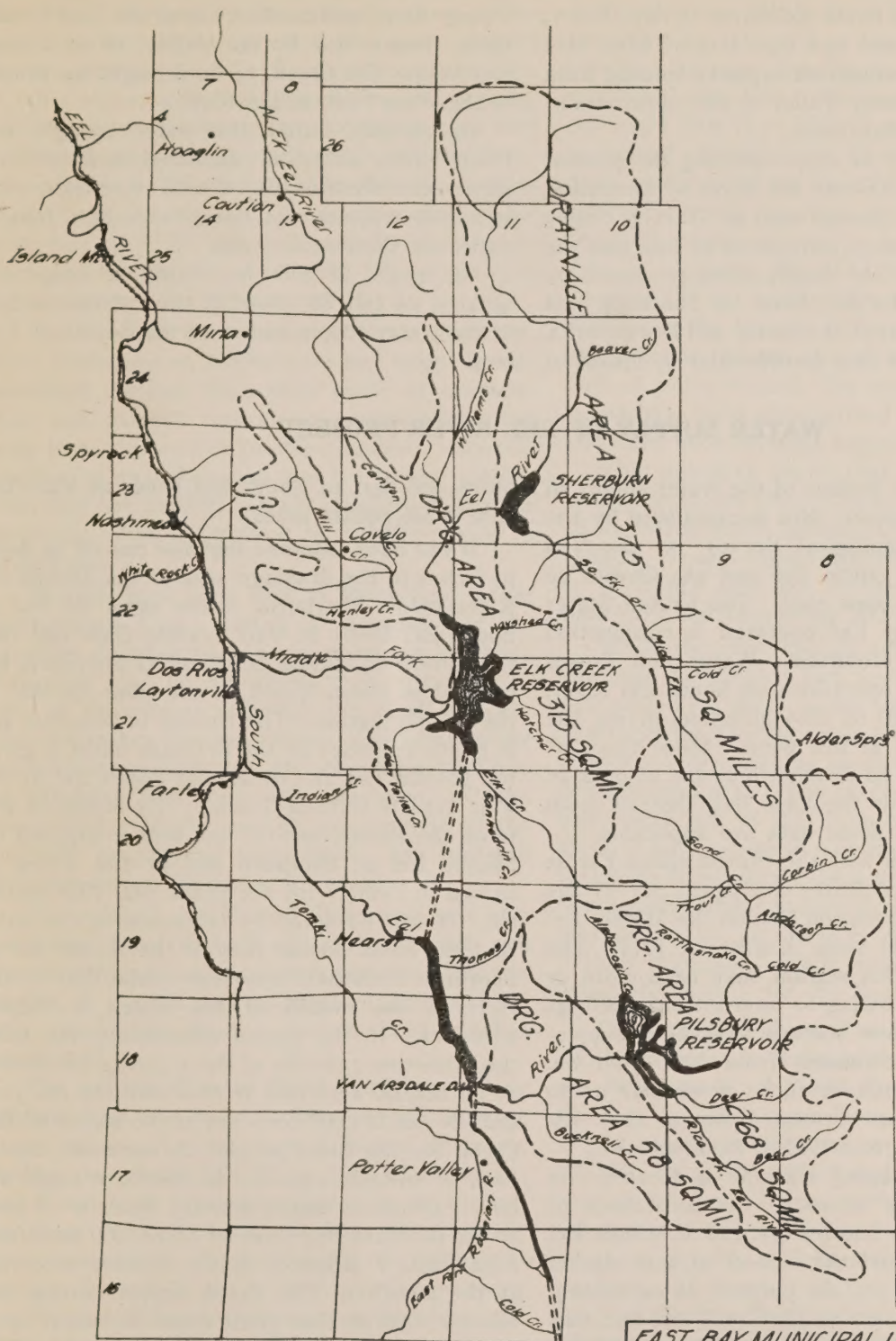
forms of aqueduct, to the reservoirs of the District by gravity. The aqueduct would be in rough country most of the way, and would involve numerous tunnels and pressure pipes.

Three surveys for an aqueduct line from the power plant in Potter Valley to Carquinez Strait have been made; a high line, surveyed by the East Bay Water Company, to deliver water into the District by gravity, and two low lines on different grades, surveyed by the Snow Mountain Water and Power Company. The latter would both require pumping.

The capacity of the Snow Mountain Water and Power Co.'s plant is about 300 cubic feet of water per second. This flow is available from the present works only a part of the time; and whether or not the present supply could feasibly be increased by enlarging the Pillsbury reservoir is a question that deserves careful study as there is serious doubt concerning the feasibility of raising the present dam so as to increase the storage capacity of the reservoir.

Surveys show that it is feasible to bring water from the Middle Eel to Van Arsdale Dam by building a dam on the Middle Eel just below the junction of the North and South Forks of the river, and by building a series of tunnels from the reservoir thus formed to Van Arsdale diversion dam, which is at about the same elevation as the ground at the junction of the North and South Forks of the Middle Eel. Apparently a fair site for a dam can be found at the proposed location, but its foundation conditions have not been investigated. Whatever grade is used in carrying the waters from the Middle Eel to Van Arsdale diversion dam would have to be obtained by raising the water in the Middle Eel by means of the storage dam and the necessary storage would have to be provided above that elevation. There appears to be no good reason why this plan could not be carried out, but the subject needs further investigation for verification of the plan.

The Eel River project, for supplying water to the East Bay District, contemplates the use and extension of the present storage and diversion works of the Snow Mountain Water and Power Company, comprising the Pillsbury reservoir on South Eel River at Gravelly Valley controlled by a masonry dam 100 feet high; the Van Arsdale combination concrete and earth div-



EAST BAY MUNICIPAL UTILITY DISTRICT
OAKLAND CALIFORNIA

CATCHMENT AREA
OF
EEL RIVER PROJECT

Drawn by: H.B.F.	Scale: 1" = 8 Miles
Traced by: H.B.F.	Date: August 26, 1924
Checked by: F.W.H.	
Approved by: F.W.H.	Nº DH 25

ersion dam on the South Eel River at Cape Horn; the diversion tunnel and pipe line of 5,067 feet length and 350 second feet capacity leading from Cape Horn to Potter Valley in the upper drainage basin of Russian River.

The possibility of supplementing the present available supply of South Eel River by increasing the height of the present dam at Gravelly Valley to 150 feet, has been considered as has also the supplementing of the supply, thus produced, by storage on Middle Eel River at Sherburn just below the junction of the South and North forks, and conveyance of this stored water by means of

a long tunnel and conduit line to the Van Arsdale Dam, thence into Potter Valley, or at a point just below Elk Creek, to be brought by tunnels to the West Fork of Eel River.

As already stated, the water brought into Potter Valley would be conducted, in either case, thence into the East Bay District by means of an aqueduct crossing the Sacramento-San Joaquin outlet at Carquinez Strait.

On page 23 will be found a map designated as DH 25 showing the catchment area of the water supply source of the Eel River Project.

WATER SUPPLY OF EEL RIVER PROJECT

In making the studies of the water supply of the Eel River project, data accumulated by the United States Geological Survey at the Van Arsdale dam on South Eel and at Covelo on Middle Eel have been used. The United States Geological Survey has operated in conjunction with the Snow Mountain Water and Power Company gaging operations on South Eel River, for the years 1910 to 1924 inclusive, giving the flow of the river at this point. Since this station is so located as to determine the amount of water available for the East Bay District from South Eel River, these data are applicable.

In co-operation with the United States Forest Service, the United States Geological Survey has operated a gaging station also on the Middle Eel River near Covelo since August 22, 1911. The data secured at this station have been more or less fragmentary owing to intermittent readings of the gage. These records have been supplemented through estimates from data from the Van Arsdale station in such a manner as to make a continuous estimated annual flow for Middle Eel River from 1911 to 1924 inclusive.

The Covelo gaging station is located on Middle Eel River between the confluence of Middle Eel and its South Fork and of Middle Eel and Elk Creek; and the run-off at this station has been utilized for the purpose of estimating the flow at the mouth of Elk Creek and also that at the mouth of the South Fork. The run-off has been determined on the basis of proportionality of run-off to area of drainage basins. The drainage area of the Middle Eel River at Sherburn at the mouth of the South Fork is approximately 375 square miles and the drainage area at the mouth of Elk Creek is greater than this by 315 square miles. The drainage area of the Middle Eel river at the Covelo station is 415 square

miles and that of South Eel River at Van Arsdale is 336 square miles.

It has been assumed that the run-off in depth in inches in the drainage area of the Middle Eel River below Sherburn is the same as that of South Eel River at Van Arsdale Dam and that the run-off of Middle Eel River at Sherburn, expressed in inches depth, is the same as that at the Covelo station. The run-off in acre-feet and in depth in inches on the drainage basin is given for Middle Eel at Covelo and South Eel at the Van Arsdale Dam in Table 5. By means of this table the annual run-off has been computed for Middle Eel at Sherburn and at Elk Creek as shown in Table 7 for the years 1909 1924 inclusive. It will be noted by reference to this table that the mean annual flow of the Middle Eel at Sherburn is 596,000 acre-feet, while that of the river at the mouth of Elk Creek is 992,000 acre-feet. In the period covered by the table the minimum run-offs at these points are shown to be 122,000 acre-feet at Sherburn for the year 1923-24 and 174,000 acre-feet at the mouth of Elk Creek for the same period. A reservoir, therefore, of suitable capacity at Sherburn could deliver a minimum supplementary quantity of water for the East Bay District of 122,000 acre-feet. Also Table 7 indicates that a suitable reservoir at the mouth of Elk Creek supplementing the natural flow at that point could be relied upon to furnish a supply of 174,000 acre-feet. The year 1923-24 is markedly worse than any other year in the period studied, the next worst year being that of 1919-20 in which the supply at either point is over 200 per cent of that available for 1923-24.

The reservoir site at Gravelly Valley occupied by the Pillsbury Reservoir, constructed by the Snow Mountain Water and Power Company,

has been surveyed by the company to an elevation considerably in excess of that now occupied by the present reservoir. From these survey data, a table, showing the submerged area and capacity for various elevations up to that involving a dam 150 feet high, has been made and is included herein as Table 6. This table shows that the present capacity of the reservoir is approximately 73,200 acre-feet, or 94,900 acre-feet with flashboard control, and the capacity for a dam 150 feet high is approximately 214,800 acre-feet.

In order that the behavior of the larger Pillsbury Reservoir of 214,800 acre-feet might be determined, studies have been made of evaporation and rainfall records to ascertain the net loss from this source on the reservoir. Consideration of available data has led to the conclusion that the evaporation on Pillsbury Reservoir might be taken to be about 54 inches per year in a land-pan.

Records have been kept at Dodgeland in the Sacramento Valley and it is assumed that the monthly distribution of evaporation on Pillsbury Reservoir may be considered to be the same as that at Dodgeland, although the total evaporation is 4 inches less per annum. Distributing the assumed evaporation of 54 inches in a land-pan at Pillsbury Reservoir on the basis of the Dodgeland monthly records, an estimate of the monthly evaporation was made for land-pan evaporation at Pillsbury Reservoir.

The rainfall at Pillsbury Reservoir was also estimated from rainfall records at Ukiah, and the monthly net evaporation computed. The net results of rainfall and evaporation derived from this computation show a gain of about 9 inches per annum.

The monthly flow of South Eel River at Van Arsdale Dam has been disturbed by the storage in and release of water from Pillsbury Reservoir during the years 1921-22 to 1923-24 inclusive; and it has been necessary, therefore, to correct, for these storage effects, the data for the river flow supplied by the United States Geological Survey. Data as to the behavior of the reservoir for the period in question were secured from the Snow Mountain Water and Power Company; and corrections were made to eliminate the effect of storage on the normal flow of the river. These corrected results have been used in making the computations of the available water supply and of the behavior of the larger Pillsbury Reservoir.

Taking into consideration the corrections referred to in the previous paragraph, a computation on a monthly flow basis was made of the

available water supply from South Eel River for the East Bay District at the Van Arsdale dam, based on storage capacity in Pillsbury Reservoir of 214,800 acre-feet. The computation gave, for the years 1909-10 to 1923-24 inclusive, the monthly run-off of South Eel River in acre-feet, the draft available for the East Bay District from the natural flow of the river, the draft from Pillsbury Reservoir necessary to supplement this flow in supplying 200 M.G.D. for the East Bay District, the net evaporation effects on Pillsbury Reservoir, the amount of water in the Pillsbury Reservoir at the end of each month, and the amount of water wasted. The results of this computation have been summarized on an annual basis and have been brought together in Table No. 8.

This summary shows that in the period of 14 years considered there was a surplus of water in all but three years, namely, 1917-18, 1919-20, and 1923-24. It also shows that there was a deficiency of 29,415 acre-feet in the amount of water necessary for furnishing 200 M.G.D.

While the year 1923-24 shows a maximum shortage for August and September 1924 of 29,415 acre-feet, there is an estimated continued shortage for October and November of 30,900 acre-feet more, making an estimated total of 60,315 acre-feet in all. The reservoir is estimated to have been full at the close of April, 1923, and there is no wastage shown after that date to and including November 1924, a period of 19 months. The total available supply from natural flow and storage in this period is estimated to be about 291,000 acre-feet, which would have furnished about 165 M.G.D. for the East Bay District.

The seasonal indices of wetness given for the Eel River basin in Bulletin No. 5 of the California Department of Public Works, indicate that there is no other year from 1871 to date that would furnish as little water as that shown for 1923-24, the years 1884-5 and 1919-20 being the next driest ones. By use of the precipitation and the seasonal wetness indices given in Bulletin 5 for these two dry periods, and making use of the similarity of location of the Ukiah station and the Van Arsdale Dam and of the available run-off data at Van Arsdale Dam for the latter dry period, a computation has been made showing the probable available supplies for these dry periods. In the low flow period of 1919-20 it may be observed that the run-off is estimated to be 2.4 times that for 1923-24. Moreover 1918-19 was a year of little over average run-off. The drouth period of 1884-85 was preceded by 3 years of low run-off; but these flows were nearly large enough

in all cases to provide the full flow of 200 M.G.D. and the reservoir would have reached the close of the flood season of 1883-84 with sufficient water, when supplemented with the estimated 144,000 acre-feet of run-off, to have supplied a draft of 200 M. G. D. for the District during 1884-85.

If it is assumed that it is not feasible to raise the present dam at Gravelly Valley, the storage would be reduced to the present amount of about 94,900 acre-feet; and a consideration of the 18 month period from June 1923 to November 1924 leads to the conclusion that a draft of about 98 M.G.D. could be supplied for that period. During

the years 1909-10 to 1922-23, a draft of about 150 M.G.D. could have been supplied to the District without any deficiency except about 7,000 acre-feet in 1919-20.

Attention is directed to the fact that the natural flow of South Eel River at Van Arsdale Dam supplemented with 214,800 acre-feet of storage in Pillsbury Reservoir would have supplied only about 165 M.G.D. during 1924 and that this flow with the present reservoir capacity of 94,900 acre-feet would supply only about 98 M. G. D. for that year.

TABLE 5

Run-off in Acre Feet and in Inches Depth on Drainage Basins of South Eel River at Van Arsdale and Middle Eel Covello.

Year	South Eel at Van Arsdale Area 326 square miles		Middle Eel at Covello Area 415 square miles	
	Acre-feet	Inches Depth	Acre-feet	Inches Depth
1909-10	390,000	22.4	670,000	30.3
10-11	465,000	26.7	744,000	33.6
11-12	227,000	13.1	506,000	22.9
12-13	389,000	22.4	707,000	32.0
13-14	899,000	51.6	1,240,000	56.0
14-15	719,000	41.3	955,000	43.1
15-16	645,000	37.1	869,000	39.2
16-17	414,000	23.8	607,000	27.4
17-18	188,000	10.8	404,000	20.1
18-19	423,000	21.9	703,000	31.8
19-20	126,000	7.2	268,000	12.1
20-21	692,000	39.8	1,040,000	47.0
21-22	256,000	14.7	512,000	23.2
22-23	272,000	15.6	530,000	23.9
23-24	53,400	3.1	136,000	6.1
Mean	410,000	23.6	659,000	29.8

Table 6

Elevation, Area, Capacity Quantities for Pillsbury Reservoir on South Eel River at Gravelly Valley

Contour Elevation	Area in Acres	Capacity in Acre-feet
1800	0.0	0.0
1810	24.6	123.3
1820	77.4	633.8
1830	196.6	2,003.9
1840	381.4	4,894.2
1850	618.7	9,895.1
1860	850.4	17,240.7
1870	1,097.5	26,980.1
1880	1,377.7	39,356.1
1890	1,690.4	54,696.6
1900	2,002.9	73,163.1
1910	2,337.2	94,863.6
1920	2,668.8	119,893.6
1925*	2,825.7*	134,022.1*
1930	2,982.6	148,150.6
1940	3,322.3	179,675.1
1950	3,705.1	214,812.1

* By interpolation.

ESTIMATES OF COST

An estimate of the cost of the development of a 200 M.G.D. delivery has been made for the Eel River Project. The development is assumed to be made in three units of 50 M.G.D., 75 M.G.D. and 75 M.G.D., to suit the estimated growth of the population of the District. These units are assumed to be completed respectively in 1928, in 1941, and in 1974. This plan of development is based on bringing the water into the District, either by Carquinez Strait either by gravity or with a 150 foot lift into San Pablo Reservoir, or by San Pablo Strait, with a 300 foot lift into this

reservoir. For comparison purposes present worths of the costs of the units are computed from their mid-construction periods with reference to the mid-construction period of the first unit. The present worths of the estimated costs are \$55,879,000 for the gravity line, \$52,227,000 for the 150 foot lift and \$52,261,000 for the 300 foot lift.

The estimates contemplate the raising of the Gravelly Valley Dam to a height of 150 feet and bringing the water into the District by a closed aqueduct of pipe lines, box conduits, and tunnels.

TABLE 7

Estimate in acre-feet and inches depth of run-off of Middle Eel River at Sherburn and at Elk Creek

MIDDLE EEL RIVER At Sherburn Area: 375 Sq. Mi. Run-off			MIDDLE EEL RIVER Bet. Sherburn and Elk Creek Area: 315 Sq. Mi. Run-off		MIDDLE EEL RIVER At Elk Creek Area: 690 Sq. Mi. Run-off	
Year	Acre Feet	Inches Depth	Acre Feet	Inches Depth	Acre Feet	Inches Depth
1909-10	606,000	30.3	376,000	22.4	982,000	26.7
1910-11	672,000	33.6	448,000	26.7	1120,000	30.4
1911-12	458,000	22.9	220,000	13.1	678,000	18.4
1912-13	640,000	32.0	376,000	22.4	1020,000	27.7
1913-14	1120,000	56.0	866,000	51.6	1990,000	54.1
1914-15	862,000	43.1	694,000	41.3	1560,000	42.4
1915-16	788,000	39.2	623,000	37.1	1410,000	38.3
1916-17	548,000	27.4	400,000	23.8	948,000	25.8
1917-18	402,000	20.1	181,000	10.8	583,000	15.8
1918-19	636,000	31.8	368,000	21.9	1004,000	27.2
1919-20	242,000	12.1	121,000	7.2	363,000	9.9
1920-21	940,000	47.0	668,000	39.8	1610,000	43.7
1921-22	464,000	23.2	247,000	14.7	711,000	19.3
1922-23	458,000	23.9	262,000	15.6	720,000	19.6
1923-24	122,000	6.1	52,000	3.1	174,000	4.7
Mean	596,000	29.8	396,000	23.6	992,000	27.0

TABLE 8

Summary of South Eel River Water Supply Available for East Bay District for Draft of 200 M.G.D.

Year	Run-off in Ac. Ft.	Draft from Natural Flow for E.B. Dist. Ac. ft	Required Draft from Pillsbury Res. for E.B. Dist. Ac. ft.	Evaporation Loss from Pillsbury Res. Ac. Ft.	Amount of Water in Pillsbury Res. at Lowest month Ac. Ft.	Date of Lowest Stage in Yearly Cycle	Surplus or Deficiency (-) of water Ac. Ft.
1909-10	390,151	136,051	88,349	+3,310	99,071	Dec., 1910	246,780
10-11	465,240	135,440	88,960	+1,650	109,230	Dec., 1911	220,921
11-12	227,230	122,630	101,770	+ 780	140,190	Oct., 1912	4,940
12-13	388,520	147,320	77,080	+2,830	122,943	Nov., 1913	175,110
13-14	899,082	139,282	85,118	+2,920	113,009	Dec., 1914	676,483
14-15	718,963	139,863	84,537	+2,060	131,583	Nov., 1915	483,249
15-16	644,967	129,967	94,433	+2,820	113,067	Nov., 1916	441,173
16-17	413,650	132,550	91,850	+1,380	97,829	Jan., 1918	186,347
17-18	187,851	91,751	132,649	+ 810	73,641	Dec., 1918	0
18-19	423,359	116,059	108,341	+1,020	72,268	Feb., 1920	172,201
19-20	126,282	72,182	152,218	+1,300	28,011	Oct., 1920	0
20-21	692,093	144,393	80,007	+3,090	106,812	Jan., 1922	370,451
21-22	278,959	123,759	100,641	+ 810	128,750	Nov., 1922	51,772
22-23	176,233	131,433	92,964	+2,950	81,083	Jan., 1924	66,330
23-24	53,412	45,382	179,018	+3,820	0	Aug. and Sept., 1924	-29,415
Means	412,399	120,538	103,862	+2,104			204,422

* This is not the lowest stage reached during this cycle, but only the stage at the last month of record.

Mokelumne River Project

DESCRIPTION AND PRESENT DEVELOPMENT

The Mokelumne River rises in the Sierra Nevada Mountains and flows in a nearly westerly direction into the San Joaquin River near Central Landing. The drainage area of the river at Clements, where it emerges from the foothills, is 632 square miles. This river has three principal branches, known as the North Fork, the Middle Fork, and the South Fork. The drainage areas of these tributaries are, respectively, 370 square miles, 75 square miles, and 76 square miles.

The upper part of the basin has a considerable width, but at the junction of the North and South Forks, where the elevation is about 2,000 feet, the river is in a narrow canyon with its divides very close to it. Below this point, the drainage basin is very narrow. Hence, the water supply comes from the higher mountains mostly above 2,000 feet in elevation. The drainage basin is also practically uninhabited, there being about one inhabitant to the square mile in this portion. There are no good roads, nor prospects of any considerable industrial or other development in this region, and the basin lies largely in the El Dorado and Stanislaus National forests, making ideal sanitary conditions. The water is soft and pure and its general desirability ranks very high. There are no large developments on the Mokelumne River that would interfere with the use of its waters for the East Bay District.

The Pacific Gas and Electric Company has developed a portion of the water supply of the North Fork of the river for power purposes in a plant at Electra, a few miles above Mokelumne Hill. This power system includes 5 small storage reservoirs aggregating about 26,000 acre-feet at Twin Lakes, Upper Blue Lake, Lower Blue Lake, Meadow Lake, and Bear River. Water from these reservoirs is released into the natural stream channels and flows into the headworks of two ditches on the North Fork, one having a capacity of 135 second feet, and the other 75 second feet. These two ditches parallel each other along the northerly side of the river and each has a small forebay reservoir and penstock leading down to the powerhouse on the main river. The head from the higher reservoir is 1466 feet, and that from the lower 1266 feet. The powerhouse has a total generating installation of 20,000 K.V.A., and 30,000 H.P. at its water wheels.

It will be noted that these diversions of water are returned to the river.

There are two other small ditches diverting waters from tributaries of the North Fork for mining purposes. These small canals are known as the Jackson and Volcano ditches, and have capacities of 20 and 35 second feet respectively. Very little water is now diverted by them.

The Clark ditch diverts a small amount of water from the upper portion of South Fork for mining purposes. This canal has not been in service recently. Further down, the Mokelumne ditch diverts a small quantity of water from the South Fork for Mokelumne Hill and territory beyond, terminating near the Town of Wallace. This ditch seems now also to be abandoned.

A privately owned reservoir site, known as Railroad Flat, has been surveyed and a little construction work done on the foundation of a dam located just below the junction of the Licking Fork with the South Fork about 2 miles north of the Town of Railroad Flat. In connection with this scheme, it has been proposed to build a small reservoir on the Middle Fork about 2 miles northeast of the mouth of Licking Fork to divert the storage of this reservoir, by means of a canal and a short tunnel, into a branch of Licking Fork thence into the reservoir above described. The ultimate feasible capacity of this reservoir, with a dam about 300 feet high, is in the neighborhood of 60,000 acre-feet.

The Mokelumne Project contemplates the construction of a high dam on the Mokelumne River a few miles above Lancha Plana and the conducting of water from this dam across the San Joaquin Valley through the Coast Range into the East Bay District. Two dam sites exist, one just below the mouth of Salt Gulch, and the other about a mile farther down stream, about 4 or 5 miles above the Town of Lancha Plana. By building a dam at either of these points, to a height exceeding 300 feet, it is possible to divert the surplus water of Mokelumne River over the divide to the northward into Jackson Creek, a tributary of Dry Creek. Below the junction of these two creeks there is a dam site on Dry Creek where there can be constructed a reservoir of very large capacity that would store nearly all of the surplus waters of the Mokelumne River. The reservoir on Dry Creek is called the

Dry Creek, or Arroyo Seco, Reservoir. The reservoir on the Mokelumne River is called the Lancha Plana Reservoir.

The elevation of the spillway from Lancha Plana Reservoir into Dry Creek would probably be placed between 550 and 575 feet above sea level. Allowing 50 feet of the upper part of the reservoir for storage purposes, a minimum elevation of 550 to 525 feet above sea level would obtain as against an elevation of 315 feet at the flow line of the San Pablo Reservoir, and of 475 feet at the flow line of the Upper San Leandro Reservoir into which it is proposed to bring the water. It would thus be possible to carry the water to these reservoirs either by gravity alone, or partly by gravity and partly by pumping in accordance with requirements of economy.

The mean annual flow of the Mokelumne River at Lancha Plana Reservoir is about 864,000 acre feet; and the works proposed would permit the complete control of this mean supply by use of Arroyo Seco and Lancha Plana reservoirs. By these means it is possible not only to supply the East Bay District, but to supply water for the irrigation of all of the irrigable lands properly tributary to the Mokelumne River, including all existing rights, riparian or otherwise, below Lancha Plana.

From the Lancha Plana Reservoir to the low country near the East Bay region, it would be necessary to carry the water under pressure in order to lift it to the elevation necessary for storage and use. Whether this elevation be attained by pressure from the reservoir, or by pumping, it will be necessary to have two or more pressure pipes to provide the ultimate capacity of 200 M. G. D. The construction of all but one of these could be deferred for several years, as one large pressure pipe would provide a water supply for the Bay Region for a number of years. Thus the interest on the latter unit would be saved for a term of years, and the initial investment required could be brought within the district's bonding limit.

The most convenient and economical location for the aqueduct would pass between Lodi and Stockton and cross the San Joaquin River near the railroad crossings of these streams, thence conveniently near Oakley, Antioch, Pittsburg, Bay Point, Concord, and Walnut Creek into San Pablo Reservoir and Upper San Leandro Reservoir. From Bay Point a branch line could be extended to Martinez,

Port Costa, Crockett, Vallona, Oleum, Hercules and Giant.

At the last crossing of the San Joaquin River a pumping plant might be installed to pump water from that level for a temporary supply for the District. By concentrating construction work on this plant and the pipe lines to the westward of it, water could be brought to the East Bay region more quickly than by any other known method.

The waters of the San Joaquin are all appropriated throughout the irrigation season and many storage reservoirs exist for holding the winter and flood waters for summer use, but there is, in all normal years, a large surplus flowing to waste in this stream during the winter, and, while this supply would not be satisfactory as a permanent solution of the water supply problem, draining as it does immense areas of settled and irrigated lands, yet, in the winter when the pollutions are most diluted, it could be used by discharging it into the San Pablo Reservoir and filtering and treating the water drawn from that reservoir through the present filtration plant. For this purpose the San Joaquin River water is much preferable to the Sacramento as there is no pollution in it corresponding to the sewage discharges of the City of Sacramento, or the drainage from the rice fields in the Sacramento Valley. All the important cities in the Upper San Joaquin Valley treat their sewage or use it for irrigation, which greatly minimizes these pollutions. The City of Stockton is situated below the point of diversion of the San Joaquin River for the proposed pumped supply. This plan for an emergency supply could be made to fit into the plans for the permanent supply so as to involve very little construction that would need to be discarded when the permanent supply was made available.

The Lancha Plana dam, built to a height of 325 feet, is necessary as a diversion to supply water to the great reservoir on Dry Creek which could not otherwise be utilized, as its local drainage is too small for this purpose. The Lancha Plana dam is too expensive to be provided for this purpose by the irrigation interests of Mokelumne Valley, and would be constructed free of cost to that valley by the East Bay District, and serve as a diversion dam to make their irrigation storage on Dry Creek feasible and economical.

The water would be taken from the Lancha Plana reservoir through a tunnel and brought

across the San Joaquin Valley by means of pressure pipes to the vicinity of Pittsburg. There a pumping plant would raise it into a short tunnel through the range which extends from Mt. Diablo to Bay Point, and by means of other pipes and tunnels, the water could be delivered in Claremont reservoir and to the pipes now in use, without filtration or contamination from local supplies. The surplus would be stored in the Upper San Leandro and San Pablo reservoirs to be drawn upon as reserves. It would thus be possible to deliver the water, entirely enclosed in conduits, from the deep reservoir at Lancha Plana through the spigots in the houses of the East Bay District, without any possibility of contamination on the way, and without affording any opportunity for the growth of the organisms which require sunlight. Such a deep, narrow reservoir as that proposed at Lancha Plana is recognized by sanitary engineers as the best possible means of purifying a water supply.

Mr. Freeman's Report contains the following, on page 38:

"Detention of water in a large reservoir, here, as in other reservoirs, is the chief sanitary safeguard relied upon by the health authorities and water works officials of Boston."

Mr. Allen Hazen, one of the leading sanitary engineers of the country, says, in his report, embodied on page 38 of the Freeman Report.

"The storage of water in large reservoirs for considerable periods tends to eliminate, and actually does eliminate, nearly all the effects of pollution upon the water running into the reservoir."

Freeman says of this water:

"The quality of water obtainable from the Mokelumne River is good. If taken from a large reservoir, such as proposed for Railroad Flat, and thereafter kept in a closed conduit, it would be safe to use without filtration."

The Lancha Plana Reservoir would be such a reservoir as that mentioned and equally suitable for the purpose.

The water level in Lancha Plana Reservoir would stand above the outlet into San Pablo Reservoir by an amount varying from 260 feet maximum to 125 feet minimum, which would normally be more than 200 feet. It would thus be possible, and entirely feasible, to deliver water into San Pablo Reservoir, or Claremont Reservoir, by gravity, but the computations show that the cost of the aqueduct capacity to deliver this water by gravity would be so great that the interest charge would exceed the cost of delivering the same quantity of water near

Pittsburg and pumping it from that point to an elevation where it would run into San Pablo Reservoir by gravity.

Estimates have been made upon three plans:

(a) The delivery of 50 M. G. D. to San Pablo Reservoir by gravity;

(b) The delivery of 50 M. G. D. near Pittsburg and there pumping it 150 feet to flow into the reservoir;

(c) Delivering the water by gravity to a lower point near Pittsburg and pumping it from there to a height of 300 feet, whence it would run into the reservoirs by gravity.

Of these three plans the one involving the pumping lift of 300 feet is the cheapest when the cost of pumping and interest charges are considered. The next cheapest is the 150-foot lift, and it is probable that a lift somewhere between these amounts will be selected as the most feasible. It is, of course, desirable to have the water at this point where it can be delivered to Pittsburg, Antioch, Bay Point, Martinez, and other points on the waterfront, without pumping, and further studies are required to determine these details.

The feature of this plan which requires the longest time in construction is the Lancha Plana Dam, which can be completed in four or five years after construction begins. The other features requiring long time are the four-mile tunnel leading to San Pablo Reservoir and the long line of steel pipe between Lancha Plana and Pittsburg. It is believed that either of these features can be completed within three years, and when they are completed, and the Lancha Plana Dam built to a height of 450 feet above sea level, it will be possible to deliver water into the San Pablo and Upper San Leandro reservoirs. It is entirely possible to accomplish this work within four years, but some additional time would be required to entirely finish the Lancha Plana Reservoir to its ultimate height.

There appears to be no reason to doubt that mountain water can be delivered to the district within four years from the time construction begins, provided adequate funds are available.

The possibility of using the Mokelumne River for supplying the City of San Francisco has been investigated several times, and the data made available by these investigations shows the existence of thirteen reservoir sites aggregating in capacity 48,301 acre feet, which require dams of various heights up to 110 feet. In addition to these sites, there are two others, one on the North Fork and the other on the

South Fork, aggregating a capacity of 151,730 acre feet, and each requiring a dam 325 feet high, the feasibility of which had not been tested. The total capacity of 200,130 is about the same as the capacity of Lancha Plana Reservoir, apparently unknown at that time, as was, no doubt, the great Arroyo Seco Reservoir with a possible capacity of 1,137,000 acre feet. There are now known to be available for use, instead of fifteen small reservoirs, two large ones with a combined capacity seven times as great as the fifteen, intercepting more than double the drainage area, and so situated that the mean

run-off of this total area can be entirely conserved. This gives a radical difference in conditions from those known at the time of the earlier investigations.

Following page 32 will be found a map of the considered water development plans of the Mokelumne River Project. This map is designated as DH 61. The water supply study has been made on the basis of two different schemes or plans. These studies will be found in the following pages under the names of Water Supply under Plan One and Water Supply under Plan Two.

WATER SUPPLY UNDER PLAN ONE

Under Plan One, a preliminary study of the water supply of the Mokelumne River at Lancha Plana Reservoir site has been made, based on a dam 320 feet high on Mokelumne River above Lancha Plana, giving a storage capacity of 187,000 acre feet and with a waste way into Dry Creek, or Arroyo Seco, Reservoir at elevation 550 feet above set level, the latter reservoir being controlled by a dam 85 feet high and having a storage capacity of 220,000 acre feet.

The United States Geological Survey has maintained a gaging station on the Mokelumne River at Clements about ten miles below the Lancha Plana Reservoir site from January, 1901, to date. The flow at the Clements station has been taken to be the same as that at the reservoir outlet. The data from this source have been supplemented by estimates from May 15 to October 1, 1924, in order to complete the study for 1924.

Evaporation records have been kept by the United States Weather Bureau at Oakdale, Cal., on the Stanislaus River; and, as the location and elevation of this station is not greatly different from that of Lancha Plana and Dry Creek reservoirs, they have been deemed suitable for use in this study. At any rate, they are as suitable as any other available records for the purpose. As these records have been obtained from land-pan observations, they have been reduced by the application of a coefficient of 0.66 to make them applicable to reservoir water surfaces. The records referred to cover the period from 1920 to 1924, and the mean annual pan evaporation is 84.84 inches and the reduced mean is 56.00 inches.

Estimates of the rainfall on the Lancha Plana and the Dry Creek reservoirs have been made from Bulletin No. 5 of the Division of Engineering and Irrigation, Department of Public Works, State of California. These estimates of rainfall and those of evaporation are brought together in Table 9, and the net results of rainfall and evaporation estimated as there shown. The result shows an annual net loss of 38 inches.

In Table 10 there have been brought together the monthly percentages of use of water in the San Joaquin, Modesto, and Turlock irrigation districts and the ideal use suggested in Bulletin No. 6 of the Division of Engineering and Irrigation, Department of Public Works, State of Cali-

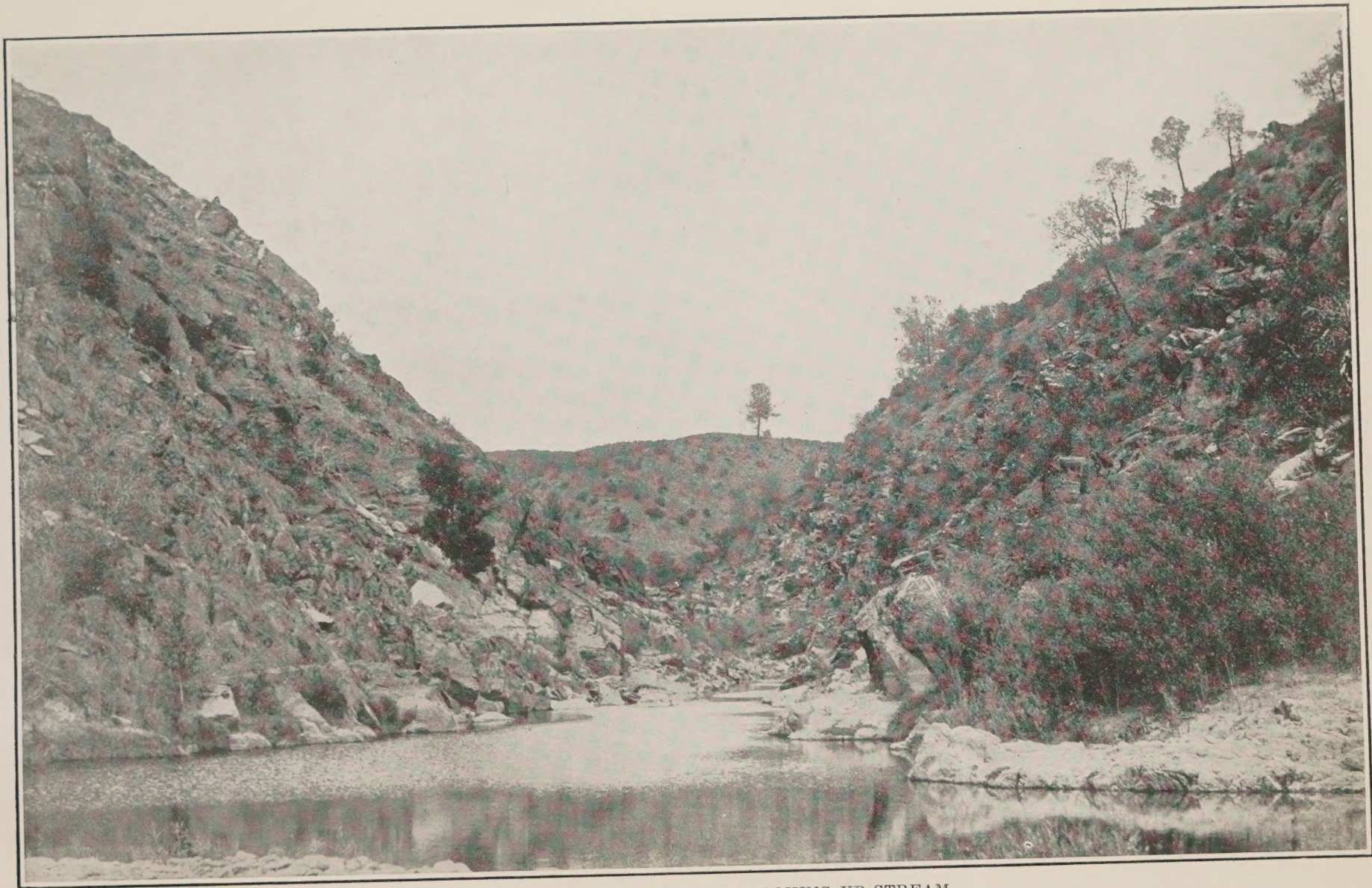
fornia. In Table 10 also are given the estimated monthly requirements for water needed by the Woodbridge Irrigation District having prior rights on Mokelumne River. The District's present canal capacity is about 500 second feet, its present irrigated area is about 10,000 acres and its ultimate irrigable area about 35,000 acres. An allowance of four acre feet per acre at the reservoir outlet for the ultimate area is assumed, making 140,000 acre-feet per annum. The monthly distribution of the use of this water is shown in Table 10.

In Tables 11 and 12 are given the contour elevations, areas and capacities of the Lancha Plana Reservoir and the Dry Creek Reservoir, as taken from the Kieffer report on the Lancha Plana Water Supply Project.

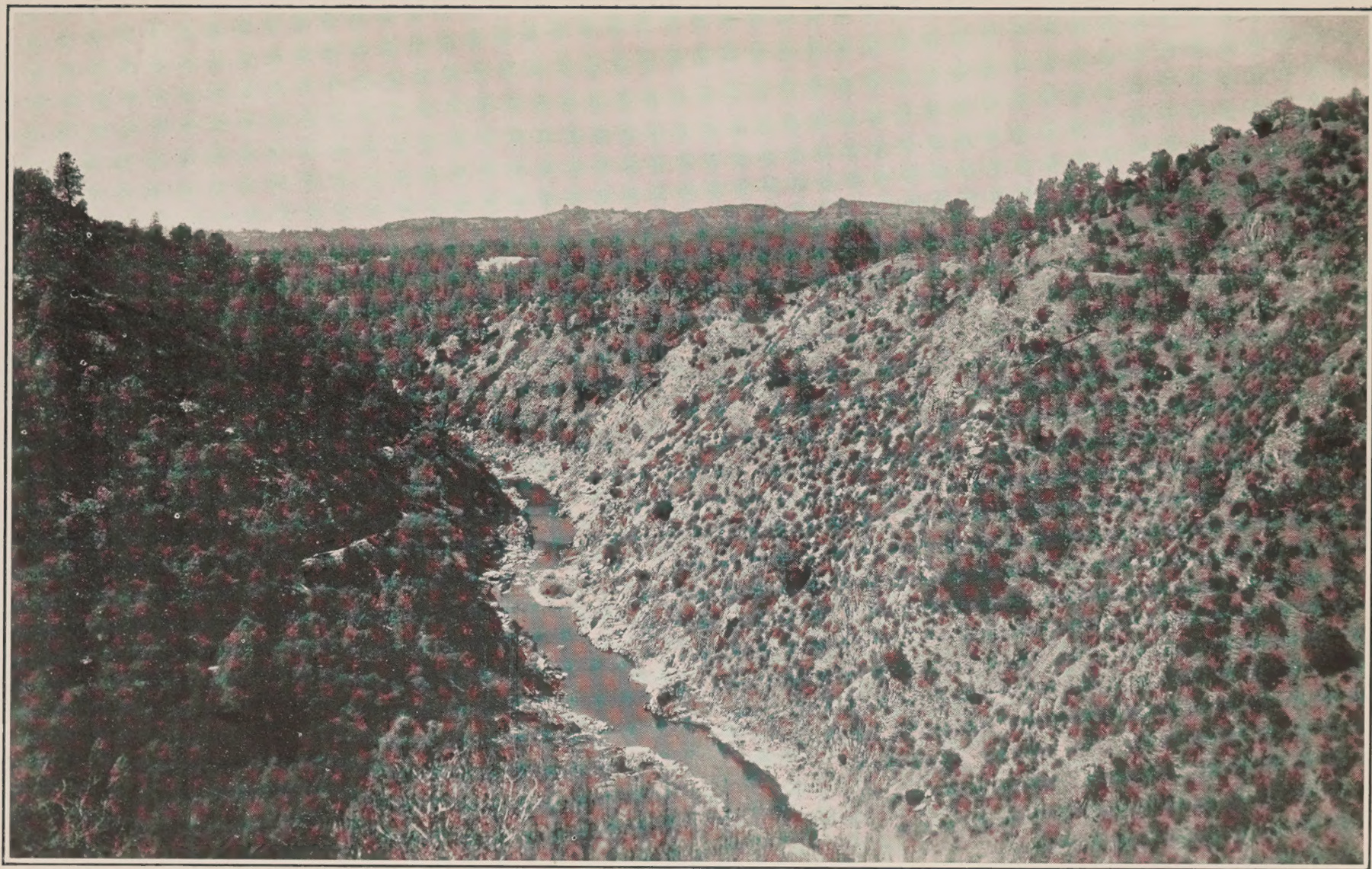
From the data just described, the disposal of the available water supply of the Mokelumne River has been worked out on the basis of monthly flow for the hydrographic years of 1901 to 1924 inclusive, based on a draft from the Lancha Plana Reservoir of 200 M. G. D. for the East Bay District and a draft from the Dry Creek Reservoir for the Woodbridge Irrigation District of 140,000 acre feet per annum, distributed as shown in Table 13. The results of the monthly computations have been summarized on an annual basis in Table 13, as there shown.

From Table 13 it will be noted that the East Bay District's supply and the prior right requirements are fully satisfied under Plan One during the 24-year period considered, and that, in addition, there is a large waste for all years except 1912, 1913, 1920, and 1924. The lowest stage of the Lancha Plana Reservoir is reached in February, 1920, at elevation 484 feet and storage of 87,780 acre feet, and that of Dry Creek Reservoir in October, 1924, with storage of 6,670 acre feet. The figures given in Table 13 do not make any allowance for seepage in the reservoir bed and make no allowance on the other hand for the run-off of Dry Creek. These quantities tend to offset each other; but will not balance fully. In fact it is probable that the run-off will exceed the seepage, especially in wet years.

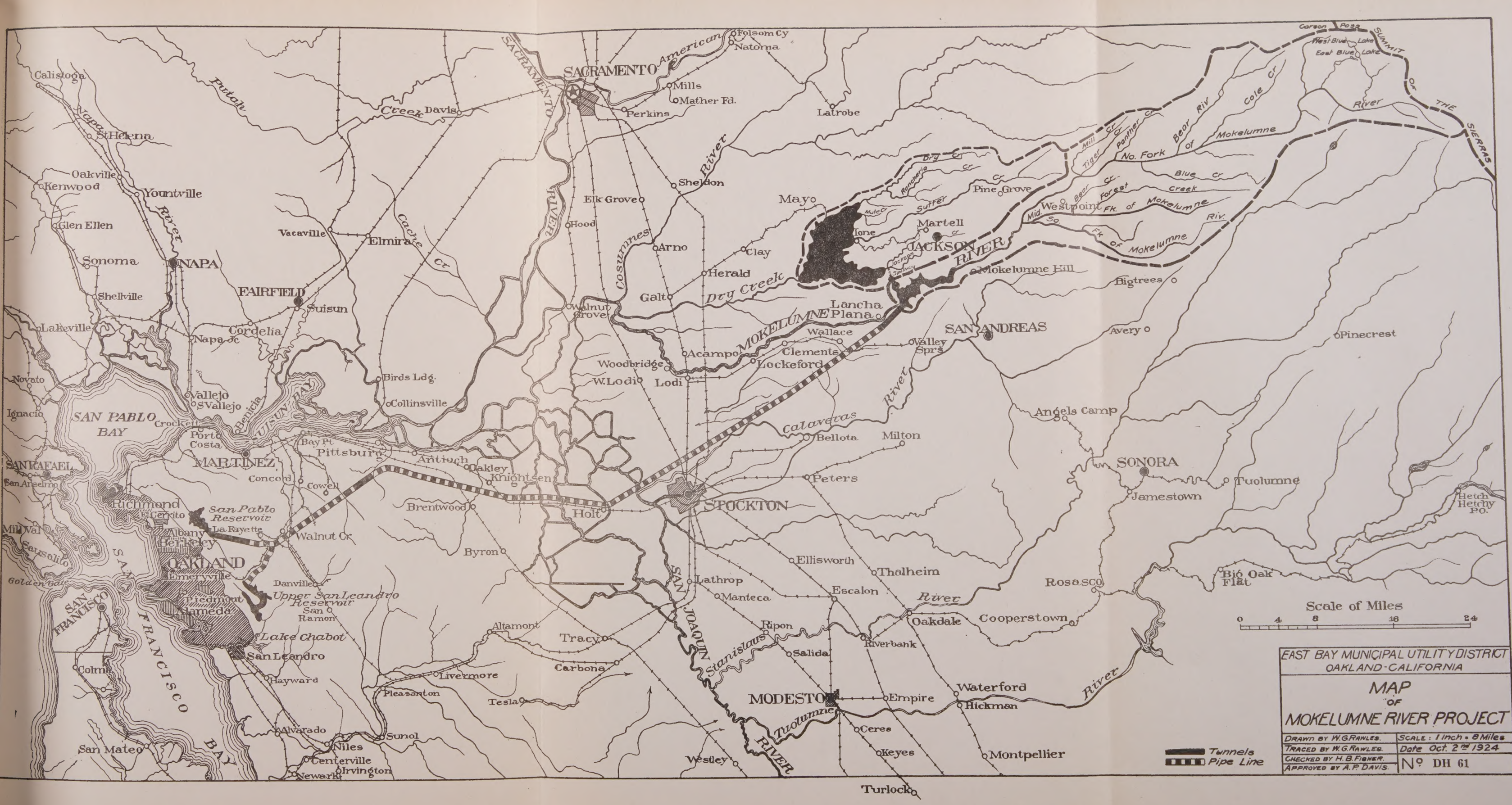
The figures at the bottom of Table 13 show that the average flow of the Mokelumne River for the period under consideration is just a little



LANCHA PLANA DAM SITE LOOKING UP STREAM



LANCHA PLANA DAM SITE LOOKING DOWN STREAM



EAST BAY MUNICIPAL UTILITY DISTRICT
OAKLAND - CALIFORNIA

MAP
OF
MOKELUMNE RIVER PROJECT

DRAWN BY W.G. RAWLES.	SCALE: 1 inch = 8 Miles
TRACED BY W.G. RAWLES.	DATE Oct. 2 nd 1924
CHECKED BY H.B. FISHER.	
APPROVED BY A.P. DAVIS.	Nº DH 61

less than half developed by the construction of the Lancha Plana and Dry Creek reservoirs with the heights of dams given under this plan.

Following page 35 will be found a hydro-

graph, designated DH 11, showing the behavior of the Lancha Plana and Dry Creek reservoirs under Plan One.

TABLE 9

Evaporation and Rainfall at Lancha Plana Reservoir and Dry Creek Reservoir, Quantities in Inches

LANCHA PLANA RESERVOIR				DRY CREEK RESERVOIR		
Month	Evapora- tion	Rain- fall	Net Loss	Evapora- tion	Rain- fall	Net Loss
October	3.90	1.18	2.72	3.90	.88	3.02
November	1.70	2.64	.94	1.70	1.98	.28
December	.90	3.72	2.82	.90	2.79	1.89
January	.81	4.39	3.58	.81	3.29	2.48
February	1.26	3.48	2.22	1.26	2.61	1.35
March	2.37	4.66	2.29	2.37	3.49	1.12
April	4.04	2.06	1.98	4.04	1.55	2.49
May	6.81	1.15	5.66	6.81	.87	5.94
June	8.00	.29	7.71	8.00	.22	7.78
July	10.19	0.00	10.19	10.19	0.00	10.19
August	9.07	0.00	9.07	9.07	0.00	9.07
September	6.95	.43	6.52	6.95	.32	6.63
Year	56.00	24.00	32.00	56.00	18.00	38.00

TABLE 10

Use of Water as Measured on South San Joaquin Irrigation District, Modesto Irrigation District and Turlock Irrigation District From Bulletin No. 6, State Division of Engineering and Irrigation, Pages 140-143, and Estimated Use for Woodbridge District

Month	South San Joaquin Irrigation District August 1915-18	Modesto Irrigation District August 1905-21	Turlock Irrigation District August 1907-21	Estimated Woodbridge District With Unregulated Flow	Corresponding Use for Total of 140,000 Acre Feet	Ideal Use Regulated Flow	Corres- ponding Use for Total of 140,000 Acre Feet
January	1.6	1.3	0.1	1.	1,500.	0.	0.
February	1.5	4.0	1.9	2.	2,500.	2.	2,500.
March	3.3	8.4	7.3	8.	11,000.	6.	8,500.
April	11.9	17.9	18.1	18.	25,000.	12.	17,000.
May	21.8	22.2	22.8	22.	31,000.	15.	21,000.
June	23.2	22.5	22.2	21.	30,000.	21.	30,000.
July	17.3	16.2	18.9	18.	25,000.	20.	28,000.
August	7.6	5.1	6.7	6.	8,500.	16.	22,000.
September	5.9	1.9	1.6	3.	4,000.	6.	8,500.
October	3.6	0.4	0.4	1.	1,500.	2.	2,500.
November	1.6	0.0	0.0	0.	0.	0.	0.
December	0.7	0.1	0.0	0.	0.	0.	0.
Year	100.	100.	100.	100.	140,000.	100.	140,000.

TABLE 11

Lancha Plana Reservoir, Contour Elevation, Area and Capacity Quantities

Elevation Feet	Area Acres	Capacity Acre Ft.
250	0	0
275	30	500
310	70	1,500
325	120	3,500
350	200	8,000
375	310	14,500
400	450	24,000
425	620	37,000
450	810	53,000
475	1,030	77,000
500	1,270	108,000
525	1,520	138,000
550	1,830	187,000

TABLE 12

Dry Creek Reservoir, Contour Elevation, Area and Capacity Quantities

Elevation Feet	Area Acres	Capacity Acre Ft.
160	0	0
170	450	5,000
180	850	10,000
190	1,450	20,000
200	2,600	40,000
210	3,800	75,000
220	5,200	125,000
230	6,900	180,000
235	7,800	220,000
240	8,700	260,000
250	10,700	360,000
260	12,800	470,000
270	15,000	610,000
280	16,900	760,000
290	18,800	930,000
300	20,600	1,137,000

TABLE 13

Summary of Mokelumne River Water Supply Available Under Plan One for East Bay District at Lancha Plana for Draft of 200 M. G. D., Quantities in Acre Feet

Year	Run-off in Acre Feet	Draft From Natural Flow for East Bay District	Draft From Lancha Plana Reservoir for East Bay District	Evaporation From Lancha Plana Reservoir	Storage in Lancha Plana Reservoir at Lowest Stage		Waste Into Dry Creek Reservoir
					Amount	Date	
1900-01	1,096,005	179,309	45,091	4,884	158,225	Sept., 1901	888,820
1901-02*					137,774	Nov., 1902	
1902-03*	200,478	61,063	13,737	5,070	170,923	Sept., 1903	136,685
1903-04	1,316,209	179,886	44,514	4,850	162,962	Oct., 1903	1,093,969
1904-05	641,825	188,546	35,854	4,760	154,780	Sept., 1905	421,798
1905-06	1,352,699	179,299	45,101	5,130	116,469	Dec., 1905	1,098,649
1906-07	1,672,000	210,100	14,300	4,900	168,130	Nov., 1906	1,439,400
1907-08	480,430	190,330	34,070	4,810	155,600	Sept., 1908	278,220
1908-09	1,147,380	168,580	55,820	4,990	125,620	Dec., 1908	914,640
1909-10	906,340	176,640	47,760	4,720	146,080	Sept., 1910	690,090
1910-11	1,526,360	193,060	31,340	5,040	126,120	Nov., 1910	1,269,980
1911-12	392,730	150,730	73,670	4,820	134,240	Feb., 1911	187,350
1912-13	423,290	171,890	52,510	4,930	135,380	Oct., 1912	190,820
1913-14	1,076,720	178,420	45,980	5,010	125,840	Dec., 1913	834,370
1914-15	822,770	171,670	52,730	5,020	137,970	Dec., 1914	599,260
1915-16	1,032,540	182,340	42,060	4,990	137,220	Nov., 1915	798,020
1916-17	868,030	189,130	35,270	4,940	151,330	Nov., 1916	640,880
1917-18	520,600	131,200	93,200	5,150	104,090	Jan., 1918	304,620
1918-19	589,870	157,970	66,430	4,980	123,270	Jan., 1919	366,400
1919-20	464,080	137,080	87,320	5,190	87,780	Feb., 1920	225,740
1920-21	864,650	191,350	33,050	4,920	142,090	Oct., 1920	626,170
1921-22	919,140	171,240	53,160	5,110	127,330	Dec., 1921	685,370
1922-23	702,830	186,430	37,970	4,860	146,030	Nov., 1922	473,150
1923-24	200,100	122,570	101,830	4,590	96,350	Dec., 1924	6,020
Mean	864,391	173,080	51,320	4,936			637,897

*Partial records only. Note.—Capacity of Lancha Plana Reservoir, 187,000 acre feet.
Capacity of Dry Creek Reservoir, 220,000 acre feet.

Continuation of Table 13

Year	Draft From Natural Flow for Irrigation Woodbridge District	Draft From Dry Creek Reservoir for Irrigation	Evapora- tion From Dry Creek Reservoir	Storage in Dry Creek Reservoir at Lowest Stage		Surplus or Deficiency
				Amount	Date	
1900-01	79,000	61,000	23,210	158,000	Aug., 1901	802,500
1901-02*				142,080	Oct., 1901	
1902-03*	30,902	57,598	20,490	146,972	Oct., 1903	100,723
1903-04	103,144	36,856	24,480	169,444	Sept., 1904	907,017
1904-05	81,500	58,500	23,520	146,090	Sept., 1905	281,632
1905-06	106,320	33,680	25,180	142,110	Oct., 1905	898,149
1906-07	129,000	11,000	24,660	177,170	Oct., 1906	1,253,640
1907-08	79,000	61,000	23,470	146,080	Sept., 1908	171,180
1908-09	107,000	33,000	24,640	142,100	Oct., 1908	720,570
1909-10	79,000	61,000	23,250	146,080	Sept., 1910	556,270
1910-11	107,000	33,000	24,760	142,100	Oct., 1911	1,071,710
1911-12	51,000	89,000	22,310	146,080	Sept., 1912	58,550
1912-13	68,000	72,000	22,560	142,100	Oct., 1912	28,260
1913-14	107,000	33,000	24,500	142,100	Oct., 1913	640,800
1914-15	102,750	37,250	24,420	169,050	Sept., 1915	440,940
1915-16	105,650	34,350	24,430	164,900	Oct., 1915	630,790
1916-17	105,750	34,250	24,530	167,700	Oct., 1916	476,250
1917-18	73,560	66,440	23,460	146,080	Sept., 1918	167,030
1918-19	51,920	88,080	22,230	126,300	Sept., 1919	223,950
1919-20	51,000	89,000	21,890	96,550	Mar., 1920	44,070
1920-21	79,150	60,850	23,740	142,100	Sept., 1921	462,280
1921-22	95,450	44,550	24,250	142,250	Oct., 1921	502,870
1922-23	87,250	52,750	23,850	154,110	Sept., 1923	319,670
1923-24	6,020	133,980	10,70	6,670	Oct., 1924	0
Mean	84,339	55,661	24,072			484,460

WATER SUPPLY UNDER PLAN TWO

The study of the water supply of the Mokelumne River at Lancha Plana Reservoir Site for Plan Two involves the same construction at the Lancha Plana Reservoir as for Plan One, but increases the height of the dam on Dry Creek to 120 feet and the storage capacity to 600,000 acre feet for the Dry Creek, or Arroyo Seco, Reservoir. The draft for the District is assumed to be 200 M. G. D., as in Plan One.

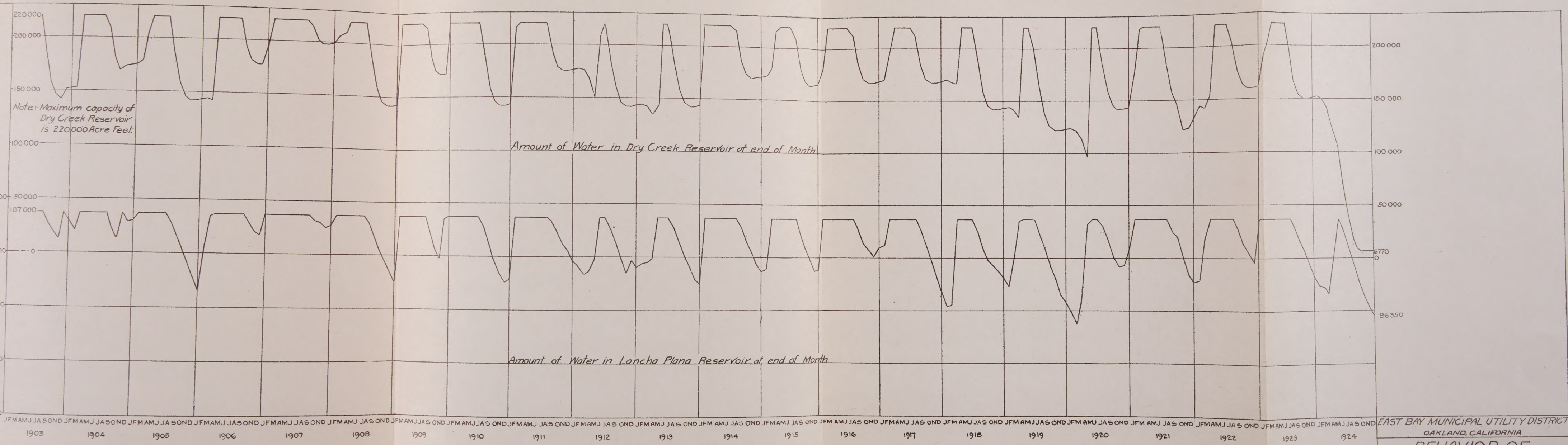
In this study the run-off of the Mokelumne River and the rainfall and evaporation on the Lancha Plana Reservoir, and the draft for the East Bay District, are the same as used for the computations in Plan One; but evaporation and seepage losses on the Dry Creek Reservoir are assumed to be balanced by rainfall on the reservoir and the run-off of Dry Creek. This assumption, it is believed, is on the side of safety. The draft for the irrigable area of the lands under Dry Creek Reservoir is assumed to be 500,000 acre feet per annum without reference to the duty of water.

On the assumption given in the preceding paragraph, the behavior of Dry Creek Reservoir has been computed on the monthly use of water for the hydrographic years 1901 to 1924. These results have been summarized by years as shown in Table 14. By reference to this table, it will be noted that an irrigation draft of

500,000 acre feet would have emptied the Dry Creek Reservoir in 1913 and 1920, and again in 1924. In these three years the shortages would have been about 29 per cent, 39 per cent, and 42 per cent respectively. As these shortages are about as large as should be permitted in an irrigation project, a draft of about 500,000 acre feet per annum would just about develop the water supply to the fullest safe extent with a Dry Creek Reservoir capacity of 600,000 acre-feet. The amount of land that can be irrigated with this draft would, of course, depend on the duty of water practiced.

Table 14 shows a mean annual surplus of 165,113 acre feet for the 22 full years of the period and an increase in the reservoir capacity of about this amount would have largely wiped out the shortages shown in the period of study. A reservoir of about 765,000 acre-feet capacity would be about the maximum feasible development under any consideration. This of course, is in addition to the 187,000 acre feet proposed for impoundment in the Lancha Plana Reservoir.

Following page 37 will be found a hydrograph designated as DH 13 showing the behavior of Dry Creek Reservoir under Plan Two, and also a diagram designated DH 49, showing a mass curve of the available water supply of the Mokelumne River Project under this plan.



Note:- Maximum capacity of Dry Creek Reservoir is 220,000 Acre Feet.

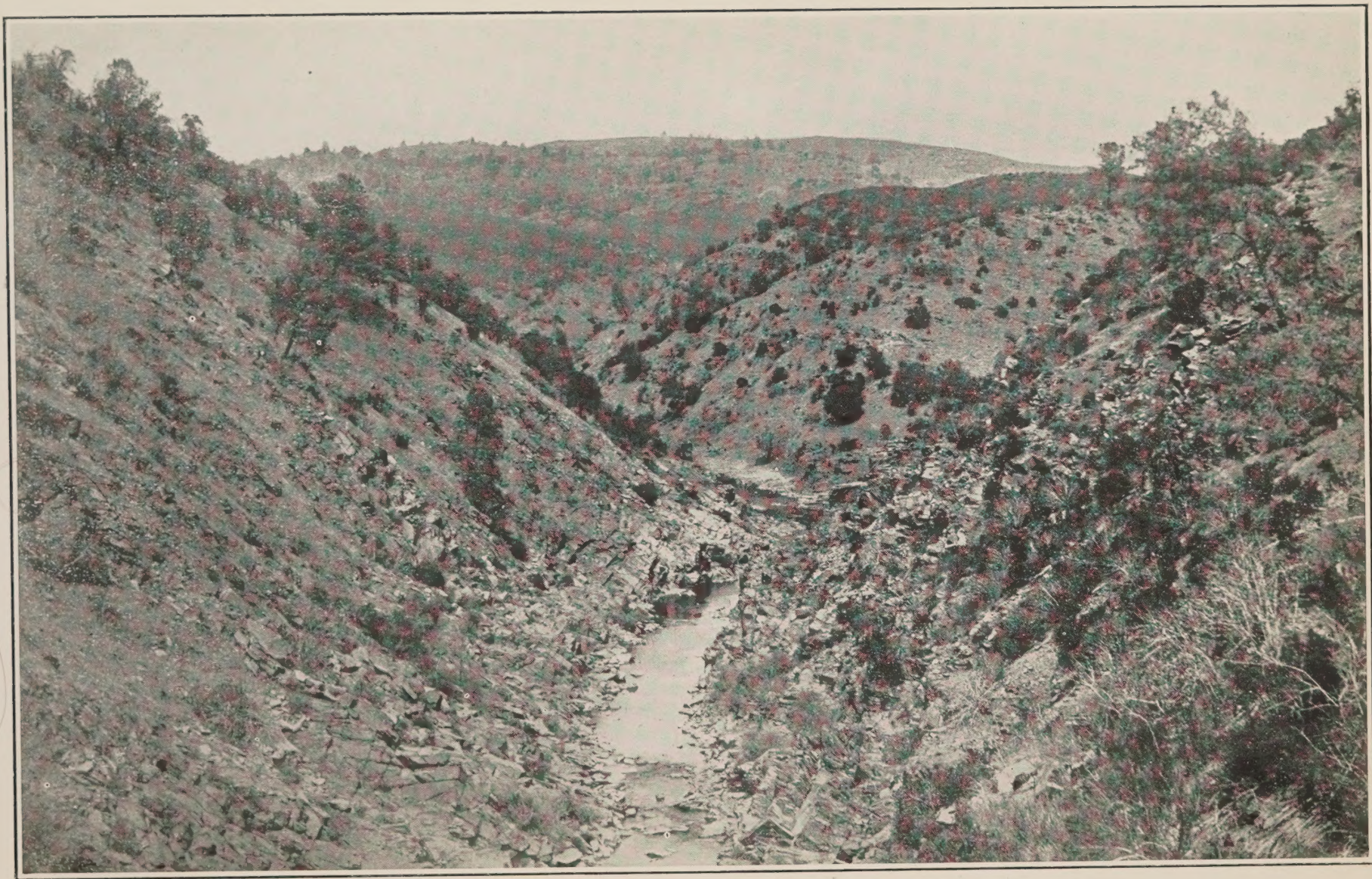
Amount of Water in Dry Creek Reservoir at end of Month

Note:- Maximum capacity of Lancha Plana Reservoir is 187,000 Acre Feet.

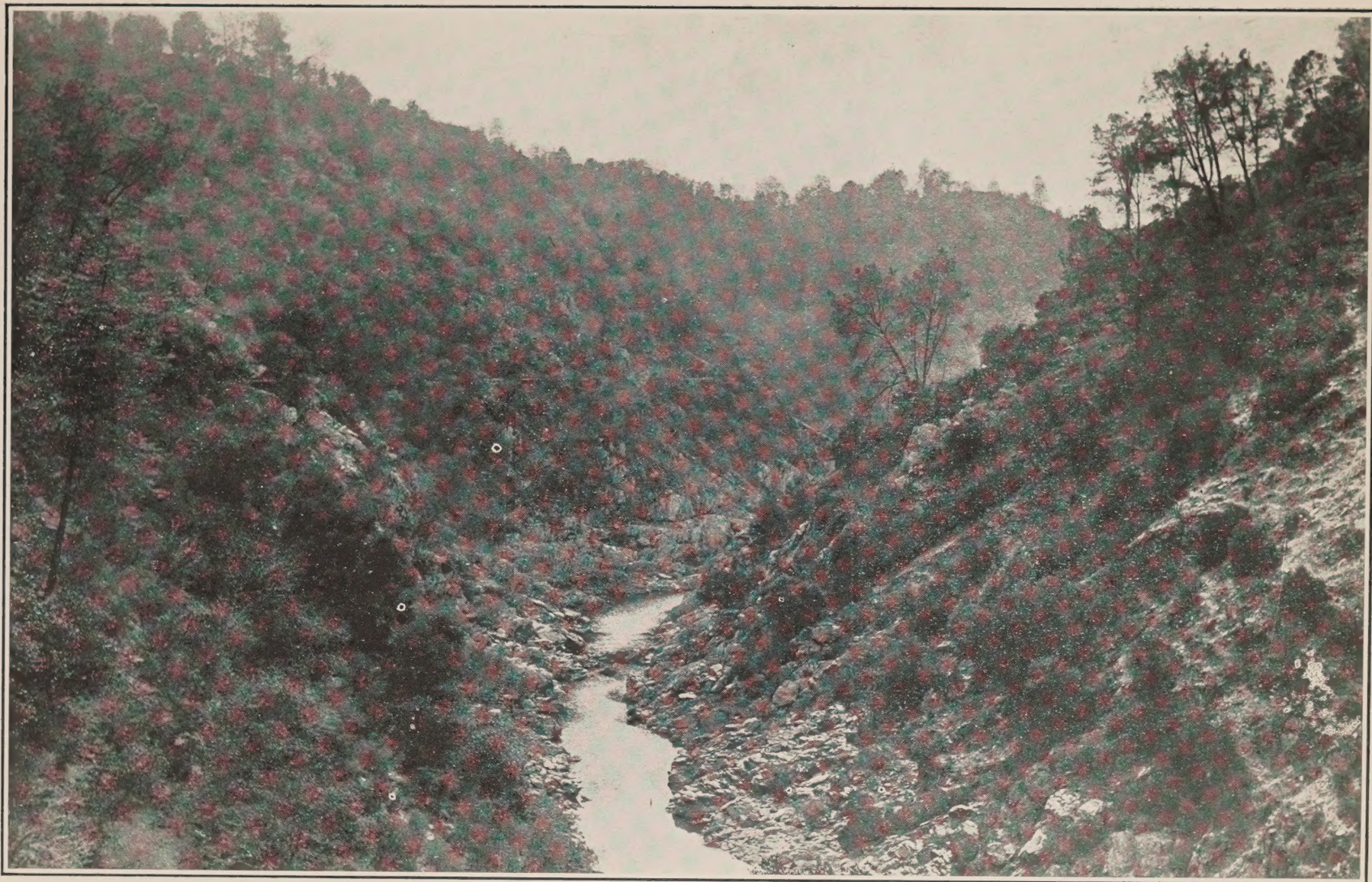
Amount of Water in Lancha Plana Reservoir at end of Month

BEHAVIOR OF LANCHA PLANA RESERVOIR AND DRY CREEK RESERVOIR WITH DRAFT OF 200 M.G.D FOR EAST BAY MUNICIPAL UTILITY DISTRICT AND OF 140,000 ACRE FEET PER ANNUM FOR IRRIGATION USE.

EAST BAY MUNICIPAL UTILITY DISTRICT OAKLAND, CALIFORNIA	
BEHAVIOR OF MOKELUMNE RIVER RESERVOIRS	
DRAWN BY WGR.	SCALE:- AS SHOWN
TRACED BY WGR.	DATE AUG. 19 - 1924
CHECKED BY WGR-HBF.	Nº DH 11
APPROVED BY F.W.H.	



VIEW UP MOKELUMNE RIVER CANYON AT LANCHA PLANA DAM SITE



VIEW DOWN MOKELUMNE RIVER CANYON AT LANCHA PLANA DAM SITE

TABLE 14

**Summary of Mokelumne River Water Supply Available Under Plan Two for Irrigable Lands
Under Dry Creek Reservoir. Quantities in Acre-Feet.**

Year Nov.-Oct.	Waste Into Dry Creek Reservoir	Draft From Natural Flow for Irrigation	Required Draft From Dry Creek Reservoir for Irrigation	Amount of Water in Dry Creek Reservoir at End of Month	Surplus of Deficiency
1900-01	888,820	280,000	220,000	380,000	608,820
1901-02*					
1902-03*	135,685	105,902	219,098	380,902	207,783
1903-04	1,102,652	312,827	187,173	412,827	570,727
1904-05	413,115	264,190	235,810	325,942	0
1905-06	1,098,649	371,820	128,180	471,820	452,771
1906-07	1,439,400	403,120	96,880	503,120	908,100
1907-08	278,220	224,360	275,640	281,340	0
1908-09	914,640	310,450	189,550	410,450	285,530
1909-10	690,090	319,620	180,380	419,620	180,920
1910-11	1,629,980	376,750	123,250	476,750	712,850
1911-12	187,350	90,000	410,000	164,100	0
1912-13	190,820	137,480	362,520	0	-145,980
1913-14	834,370	309,950	190,050	324,370	0
1914-15	599,260	302,650	197,350	402,650	29,980
1915-16	798,020	306,650	193,350	406,650	293,870
1916-17	640,880	306,750	193,250	406,750	140,780
1917-18	304,620	208,180	291,820	211,370	0
1918-19	366,400	148,920	351,080	77,770	0
1919-20	225,740	133,620	366,380	0	-196,490
1920-21	626,170	280,150	219,850	126,270	0
1921-22	685,370	278,810	221,190	311,540	0
1922-23	473,150	262,220	287,780	234,690	0
1923-24	6,020	6,020	493,980	0	-209,290
Mean	637,897	256,115	243,885	290,815	165,113

* Partial records only.

Note:—Capacity of Lancha Plana Reservoir 187,000 acre feet and of Dry Creek Reservoir 600,000 acre feet.

ESTIMATES OF COST OF MOKELUMNE RIVER PROJECT

The estimates of cost of the Mokelumne River Project are based on the building of the Lancha Plana Reservoir and the bringing of 200 M. G. D. of water in an aqueduct from this reservoir across the San Joaquin Valley and over and through the Coast Range into San Pablo and Upper San Leandro Reservoirs. In order to do this it is necessary to provide for the prior water rights on the Mokelumne River by a contractual contribution towards the construction of Dry Creek Reservoir from which irrigable lands are to be served.

On page 39 is given a list of the principal construction features involved in this project. The list is comprised of five different sub-lists resulting from different plans of procedure in the development of the project. These five plans are divided into two groups based on the rate of development required to meet the assumed growth of the population of the District.

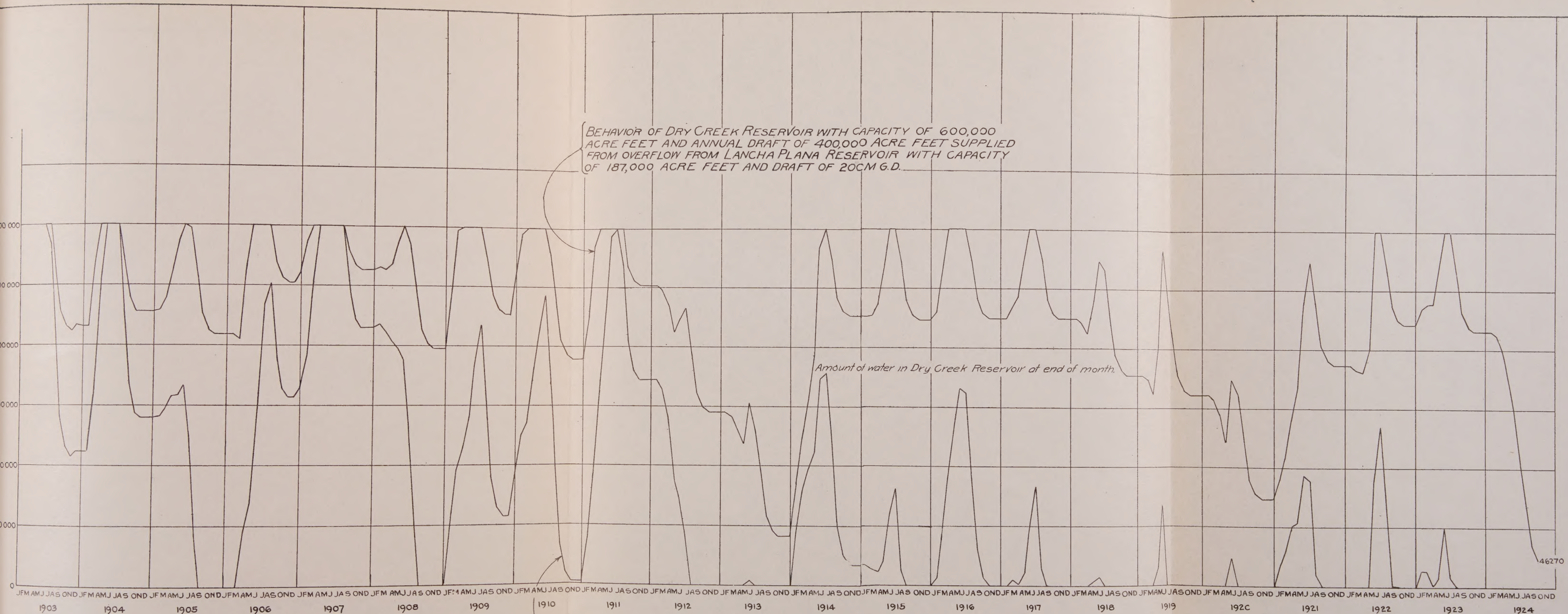
The first group consists of items 1, 2 and 3 in which the development is assumed to proceed on the basis of the installation of a first unit of 50 M. G. D. in 1924-28; a second unit of 75 M. G. D. in 1942-44, and a third unit of 75 M. G. D. in 1964-66. The cost of the first unit of this group is based on gravity flow; that of the second on a combination of gravity and pump-

ing to a height of 150 feet; that of the third on a combination of gravity and pumping to a height of 300 feet.

The second group consists of items 4 and 5 in which the development is assumed to proceed on the basis of the installation of a first unit of 100 M. G. D. in 1924-28 and a second unit of 100 M. G. D. in 1957-59. These units are both based on a combination of gravity and pumping, the first 150 feet and the second 300 feet.

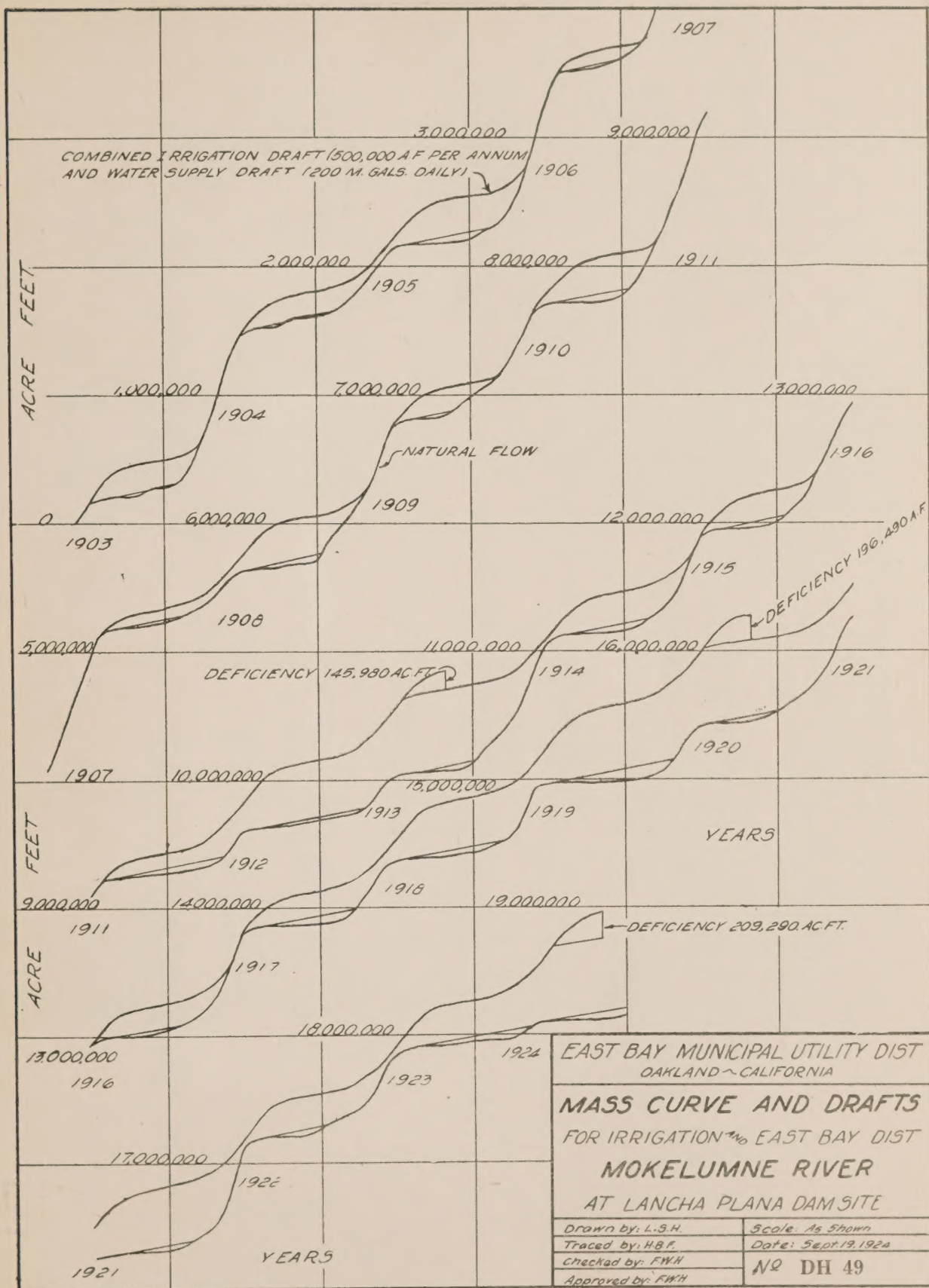
On page 40 is given a summary of the preliminary estimated costs of the various units just described and their present worths brought down to the mid-construction periods of the first units, the investment in each unit being assumed to have been made at its mid-construction period. Of the various schemes considered it will be noted that the cheapest is the combination gravity and pumping scheme involving a 300-foot lift and developments of 50 M. G. D. 75 M.G.D. and 75 M.G.D. as the estimated needs demand. The present worth of the cost of this scheme is \$51,161,000 and the cost of the first installation of this scheme is \$39,624,000.

Following the summary, tabulations will be found of detailed estimates of each of the five plans of development and also profiles of the aqueducts involved in each of them.



BEHAVIOR OF DRY CREEK RESERVOIR WITH CAPACITY OF 600,000 ACRE FEET AND ANNUAL DRAFT OF 800,000 ACRE FEET SUPPLIED FROM OVERFLOW FROM LANCHA PLANA RESERVOIR WITH CAPACITY OF 187,000 ACRE FEET AND DRAFT OF 200 M.G.D.

EAST BAY MUNICIPAL UTILITY DISTRICT OAKLAND - CALIFORNIA	
BEHAVIOR OF DRY CREEK RESERVOIR	
DRAWN BY W.G.R.	SCALE: - AS SHOWN
TRACED BY W.G.R.	DATE AUG. 21 - 1924.
CHECKED BY W.G.R.-HBF	No DH 13
APPROVED BY F.W.H.	



EAST BAY MUNICIPAL UTILITY DIST
OAKLAND ~ CALIFORNIA

MASS CURVE AND DRAFTS
FOR IRRIGATION ~ EAST BAY DIST
MOKELUMNE RIVER
AT LANCHA PLANA DAM SITE

Drawn by: L.S.H.

Scale: As Shown

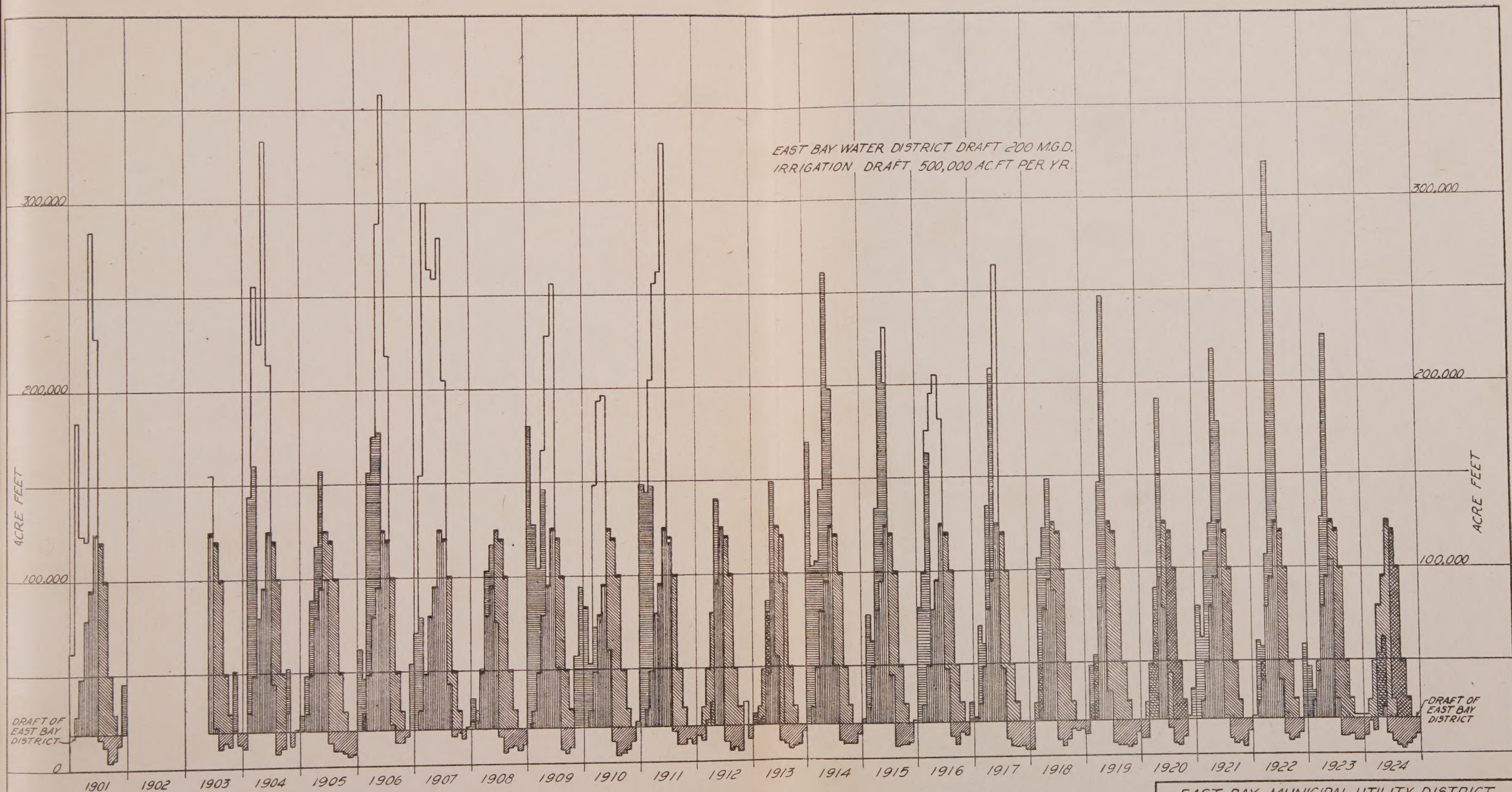
Traced by: H.B.F.

Date: Sept. 19, 1924

Checked by: F.W.H.

Nº DH 49

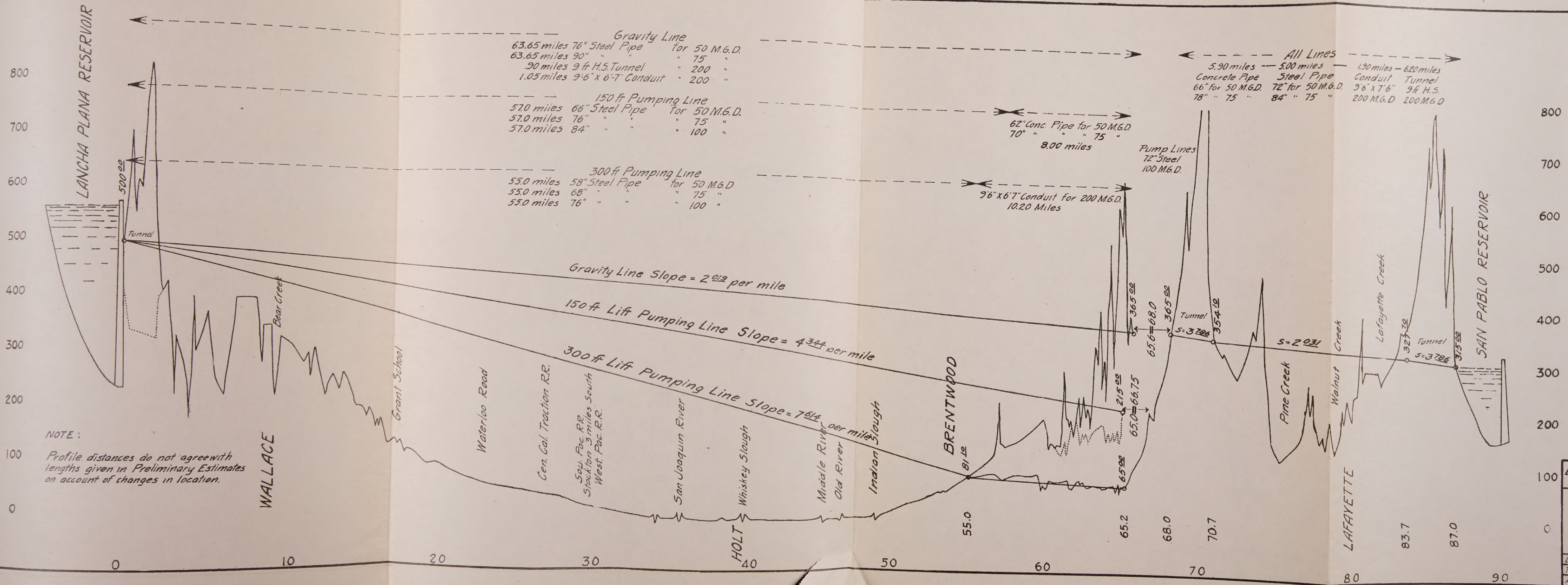
Approved by: F.W.H.



LEGEND

- | | |
|---|--|
| □ DRAFT FOR EAST BAY DISTRICT FROM NATURAL FLOW | ▨ DEFICIT IN IRRIGATION SUPPLY |
| ▨ DRAFT FOR EAST BAY DISTRICT FROM STORAGE | ■ EVAPORATION LOSS FROM LANCHA PLANA RESERVOIR |
| ▨ DRAFT FOR IRRIGATION FROM NATURAL FLOW | ▨ WATER USED TO REFILL STORAGE RESERVOIR |
| ▨ DRAFT FOR IRRIGATION FROM STORAGE | □ WATER WASTED |

EAST BAY MUNICIPAL UTILITY DISTRICT OAKLAND, CALIFORNIA	
HYDROGRAPH MOKELUMNE RIVER SHOWING WATER DISTRIBUTION	
Drawn by: L.S.H.	Date: September 26, 1924
Traced by: H.B.F.	No. DH 60
Approved by: F.W.H.	



EAST BAY MUNICIPAL UTILITY DIST.
 OAKLAND, CALIFORNIA

MOKELUMNE RIVER PROJ.
 PROFILE OF LINE
 LANCHA PLANA RESERVOIR
 TO
 SAN PABLO RESERVOIR

Drawn by: E.L.M. Date: Oct 8, 1924
 Traced by: N.D. DH 62
 Approved by:

TABLE 15

Principal Construction Features Mokelumne River Project

	First Unit 50 M.G.D.	Second Unit 75 M.G.D.	Third Unit 75 M.G.D.
Gravity Line—			
(1) Lancha Plana Reservoir—			
Riveted steel pipe 3/8" to 5/8"x76"	62.2		
Riveted steel pipe 3/8" to 11/16"x90"		62.6	62.6
Concrete pipe, 76"	2.74	2.74	2.74
Tunnel, Markley-Kirker 9'	1.1		
Kirker Creek crossing			
(2) Tunnel, Kirker-Diablo 9'	2.5		
(3) Concrete pipe 66" and 78"	2.8	2.8	2.8
(4) Tunnel, Diablo-Pine 9'	0.35		
(5) Riveted steel pipe 5/16" to 3/8"x72"	5.15		
(6) Riveted steel pipe 3/8" to 7/16"x84"		5.15	5.15
(7) Concrete pipe 66" and 78"	3.1	3.1	3.1
(8) Concrete conduit 9'6"x7'6" (covered)	2.26		
(9) Tunnel, Lafayette-San Pablo 9'	3.5		
Total length in miles	86.1	76.69	76.69
Pumping Line—150' Lift—			
Items (1) to (9) same as gravity line	19.66	11.05	11.05
Riveted steel pipe 5/16" to 9/16"x66"	58.0		
Riveted steel pipe 3/8" to 9/16"x76"		58.0	58.0
Riveted steel pipe pumping line 72"	1.2	1.2	
Concrete pipe 62" and 70"	8.0	8.0	8.0
(10) Kirker Creek Reservoir	0.15		
Total length in miles	87.01	78.25	77.05
Pumping Line—300' lift—			
Items (1) to (10) same as before	19.81	11.05	11.05
Riveted steel pipe 5/16" to 3/8"x58"	56.15		
Riveted steel pipe 5/16" to 7/16"x69"		56.15	56.15
Riveted steel pipe pumping line 72"	2.3	2.3	
Concrete conduit 9'6"x7'6" (covered)	11.05		
Total length in miles	89.31	69.5	67.2
Pumping Line—150' Lift—			
Items (1), (2), (4), (8), (9), and (10) same as before	8.76		
Riveted steel pipe 3/8" to 9/16"x84"	58.0	58.0	
(11) Riveted steel pipe 3/8" to 7/16"x90"	5.18	5.18	
Riveted steel pipe pumping line 72"	1.2	1.2	
Concrete pipe 78"	8.0	8.0	
(12) Concrete pipe 86"	5.87	5.87	
Total length in miles	87.01	78.25	
Pumping Line—300' Lift—			
Items (1), (2), (4), (8), (9), (10), (11), (12) same	19.81	11.05	
Riveted steel pipe 3/8 to 1/2"x76"	51.7	51.7	
Riveted steel pipe pumping line 72"	2.3	2.3	
Concrete pipe 72"	4.45	4.45	
Concrete conduit 9'6"x7'6" (covered)	11.05		
Total length	89.31	69.5	

TABLE 16

Summary of Preliminary Estimates Mokelumne River Project, via Kirker Creek

Item	Length in Miles	1st Unit	2nd Unit	3rd Unit	Totals
Three Unit Development					
Construction periods		1924-28	1942-44	1964-66	200
		50 M. G. D.	75 M. G. D.	75 M. G. D.	M. G. D.
1 Gravity Line— 86.1					
Estimated cost		39,372,000	\$28,101,000	\$28,101,000	\$95,574,000
Int. during construction....		3,937,000	1,405,000	1,405,000	6,747,000
Cap. pump. chgs.....		0	0	0	0
Total		43,309,000	29,506,000	29,506,000	102,321,000
Present worth		43,309,000	12,863,000	4,406,000	60,578,000
2 150-ft. Pump Lift—87.01					
Estimated cost		34,541,000	20,320,000	20,063,000	74,924,000
Int. during construction....		3,454,000	1,016,000	1,003,000	5,473,000
Cap. pump. chgs.....		2,520,000	2,600,000	4,580,000	9,700,000
Total		40,515,000	23,936,000	25,646,000	90,097,000
Present worth		40,515,000	10,435,000	3,830,000	54,780,000
3 300-ft. Pump Lift—89.31					
Estimated cost		32,167,000	13,663,000	13,173,000	59,003,000
Int. during construction....		3,217,000	683,000	659,000	4,559,000
Cap. pump. chgs.....		4,240,000	4,680,000	7,880,000	16,800,000
Total		39,624,000	19,026,000	21,712,000	80,362,000
Present worth		39,624,000	8,295,000	3,242,000	51,161,000
Two Unit Development					
Construction periods		1924-28	1957-59		200
		100 M. G. D.	100 M. G. D.		M. G. D.
4 150-ft. Pump Lift—87.01					
Estimated cost		41,685,000	23,328,000		65,013,000
Int. during Construction....		4,169,000	1,166,000		5,335,000
Cap. pump. chgs.....		4,040,000	5,080,000		9,120,000
Total		49,894,000	29,574,000		79,468,000
Present worth		49,894,000	6,207,000		56,101,000
5 300-ft. Pump Lift—89.31					
Estimated cost		37,360,000	16,522,000		53,882,000
Int. during Construction....		3,736,000	826,000		4,562,000
Cap. pump. chgs.....		6,880,000	8,900,000		15,780,000
Total		47,976,000	26,248,000		74,224,000
Present worth		47,976,000	5,509,000		53,485,000

Pumping plants located at Kirker Creek pumping to East Portal of Kirker Creek—Diablo Tunnel.

Interest during construction based on five per cent per annum of expenditures over one-half of construction period.

Present worth computed on basis of five per cent interest compounded annually.

TABLE 18
**Preliminary Estimate Mokelumne River Project Three Unit Development. Pumping Line 150 ft.
 Lift At Kirker Creek**

Items	Miles	Unit Cost	First Unit	Second Unit	Third Unit
Right of way.....			770,000		
Water rights			4,600,000		
Storage Lancha Plana Reservoir.....			6,000,000		
Riveted steel pipe—					
San Joaquin Valley—					
5/16"x66"—229' hd.....	16.6	111,000	1,843,000		
3/8"x66"—274' hd.	5.3	122,000	647,000		
7/16"x66"—320' hd.....	6.1	142,000	866,000		
1/2"x66"—367' hd.....	13.0	165,000	2,145,000		
9/16"x66"—510' hd.....	17.0	223,000	3,791,000		
Walnut Creek Valley—					
5/16"x72"—210' hd.....	4.11	122,000	502,000		
3/8"x72"—251' hd.....	1.04	132,000	137,000		
Cement lining—66'.....	*58.0	18,300	1,061,000		
—72".....	*5.15	19,900	102,000		
Rd. & Ry. X-ings, valves, manholes, etc. (all pipe)			776,000	836,000	832,000
		{ 32,000			
Pile bents	*15.0	{ 32,900	480,000	494,000	494,000
River crossings			400,000		
Concrete pipe—San Joaquin Valley 62" ..	8.0	90,000	720,000		
Walnut Creek 66".....	5.9	100,000	590,000		
Conduit—9'6"x7'6"	2.26	200,000	452,000		
Syphons, manholes, X-ings, and Misc. Str.	*2.26	10,000	23,000		
Tunnels—9'	6.35	500,000	3,175,000		
Pumping plant—Kirker Creek.....			250,000	250,000	250,000
Riveted steel pipe line—72".....	1.2		195,000	195,000	
Cement lining—Pumping line	*1.2		24,000	24,000	
Forebay and wasteway			350,000		
Kirker Creek Reservoir	.15		50,000		
Sub-Total	87.01		29,949,000		
Contingencies and administration.....			4,492,000		
Total for 30 M. G. D.....			34,441,000		
Additional pumping cap. 20 M. G. D.....			100,000		
Total for First Unit, 50 M. G. D.....			34,541,000		
Riveted steel pipe—					
San Joaquin Valley—					
3/8"x76"—239' hd.....	17.4	139,000		2,419,000	2,419,000
7/16"x76"—279' hd.....	4.7	163,000		766,000	766,000
1/2"x76"—318' hd.....	4.9	189,000		926,000	926,000
9/16"x76"—446' hd.....	31.0	254,000		7,874,000	7,874,000
Walnut Creek Valley—					
3/8"x84"—215' hd.....	4.47	154,000		688,000	688,000
7/16"x84"—250' hd.....	.68	181,000		123,000	123,000
Cement lining—76"	58.0	21,000		1,218,000	1,218,000
Cement lining—84".....	5.15	23,200		119,000	119,000
Concrete pipe—San Joaquin Calley 70" ..	8.0	109,000		872,000	872,000
Walnut Creek 78".....	5.9	132,000		779,000	779,000
Sub-Total				17,583,000	17,360,000
Contingencies and administration.....				2,637,000	2,603,000
Total for 50 M. G. D.....				20,220,000	19,963,000
Additional pumping cap. 25 M. G. D.....				100,000	100,000
Total for Second Unit, 75 M. G. D.....				20,320,000	
Total for Third Unit, 75 M. G. D.....					20,063,000
Total for 200 M. G. D.....					74,924,000
Capitalized pumping charges			2,520,000	2,600,000	4,580,000
* Duplicated mileage—not counted.					

TABLE 19

**Preliminary Estimate Mokelumne River Project Pumping Line—300 Foot Lift at Kirker Creek
Three Unit Development**

Item	Miles	Unit Cost	First Unit	Second Unit	Third Unit
Right of way.....			\$ 770,000		
Water rights			4,600,000		
Storage, Lancha Plana Reservoir.....			6,000,000		
Riveted steel pipe—					
San Joaquin Valley—					
5/16"x58"—260' hd.....	36.15	\$ 98,000	3,543,000		
3/8"x58"—313' hd.....	20.00	107,000	2,140,000		
Walnut Creek Valley—					
5/16"x72"—210' hd.....	4.11	122,000	502,000		
3/8"x72"—251' hd.....	1.04	132,000	137,000		
Cement lining steel pipe—58".....	*56.15	16,000	898,000		
Cement lining—72".....	*5.15	19,900	102,000		
Rd. and Ry. X-ings, valves, manholes, fencing, etc.			558,000	\$688,000	678,000
		{ 31,100			
Pile bents	*15.0	32,200	466,000	483,000	483,000
River crossings			400,000		
Concrete pipe—Walnut Creek Val. 66".....	5.9	100,000	590,000		
Conduit—9'6"x7'6".....	11.05	187,000	2,066,000		
Conduit—9'6"x7'6".....	2.26	200,000	452,000		
Syphons, V-ings, manholes, misc. str.....	*13.31	10,000	133,000		
Tunnels—9'.....	6.35	500,000	3,175,000		
Pumping plant—Kirker Creek.....			450,000	450,000	450,000
Riveted steel pipe line 72".....	*2.3		370,000	370,000	
Cement lining 72".....	*2.3	19,900	46,000	46,000	
Forebay and wasteway			350,000		
Kirker Creek Reservoir.....	.15		50,000		
Sub-Total			27,798,000		
Contingencies and administration.....			4,169,000		
Total for 30 M. G. D.....			31,967,000		
Add pumping capacity 20 M. G. D.....			200,000		
Total for 50 M. G. D.....	89.31		32,167,000		
Riveted steel pipe—					
San Joaquin Valley—					
5/16"x68"—222' hd.....	31.05	109,000		3,385,000	3,385,000
3/8"x84"—215' hd.....	4.47	125,000		800,000	800,000
7/16"x68"—311' hd.....	18.7	146,000		2,730,000	2,730,000
Walnut Creek Valley—					
3/8"x84"—215' hd.....	4.47	154,000		690,000	690,000
7/16"x84"—250' hd.....	.68	181,000		123,000	123,000
Cement lining—68".....	*56.15	18,800		1,056,000	1,056,000
Cement lining—84".....	*5.15	23,200		119,000	119,000
Concrete pipe—78".....	5.9	130,000		767,000	767,000
Sub-Total				11,707,000	11,281,000
Contingencies and administration.....				1,756,000	1,692,000
Total for 50 M. G. D.....				13,463,000	
Add. pumping capacity 25 M. G. D.....				200,000	
Total for Second Unit—75 M. G. D.....				13,663,000	
Total for 50 M. G. D.....					12,973,000
Add. pumping capacity 25 M. G. D.....					200,000
Total for Third Unit—75 M. G. D.....					13,173,000
Total for three unite—200 M. G. D.....					59,003,000
Capitalized pumping charges.....			4,240,000	4,680,000	7,880,000

* Duplicated mileage—not counted.

TABLE 17

Preliminary Estimate Mokelumne River Project, Gravity Line, Three Unit Development

Item	Miles	Unit Cost	First Unit	Second Unit	Third Unit
Right of way.....		\$	\$ 770,000	\$	\$
Water rights			4,600,000		
Storage, Lancha Plana Reservoir.....			6,000,000		
Riveted steel pipe—					
San Joaquin Valley—					
3/8"x76"—239'hd.	15.7	139,000	2,182,000		
7/16"x76"—279' hd.....	4.3	163,000	701,000		
1/2"x76"—318' hd.....	2.4	189,000	454,000		
9/16"x76"—446' hd.....	32.2	254,000	8,179,000		
5/8"x76"—494' hd.	8.0	292,000	2,336,000		
Walnut Creek Valley—					
5/16"x72"—210' hd.....	4.11	122,000	502,000		
3/8"x72"—251' hd.....	1.04	132,000	137,000		
Cement lining—72"	*5.15	19,900	102,000		
76"	*62.6	21,000	1,315,000		
R.. and Ry. X-ings, valves, fencing manholes, etc.			931,000	1,151,000	1,151,000
Pile bents	*15.	{ 32,900 45,200	494,000	678,000	678,000
River crossings			400,000		
Concrete pipe—San Joaquin Val. 66"....	5.9	100,000	590,000		
Walnut Creek Val. 76"	2.74	124,000	340,000		
Conduit—9'6"x7'6"	2.26	200,000	456,000		
Syphons, manholes, X-ings, etc.	*2.26	10,000	23,000		
Tunnels 9'	7.45	500,000	3,725,000		
Sub-total			34,237,000		
Contingencies and administration.....			5,135,000		
Total for First Unit—50 M. G. D....	86.1		39,372,000		
Riveted steel pipe—					
San Joaquin Valley—					
3/8"x90"—202' hd.....	13.72	165,000		2,264,000	2,264,000
7/16"x90"—235' hd.....	2.82	193,000		544,000	544,000
1/2"x90"—269'hd.	1.83	224,000		410,000	410,000
9/16"x90"—376' hd.....	6.73	298,000		2,006,000	2,006,000
5/8"x90"—418' hd.....	13.70	340,000		4,658,000	4,658,000
11/16"x90"—454' hd.....	23.80	383,000		9,115,000	9,115,000
Walnut Creek Valley—					
3/8"x84"—215' hd.....	4.47	154,000		688,000	688,000
7/16"x84"—250' hd.....	.68	181,000		123,000	123,000
Cement lining 84"	*5.15	23,200		120,000	120,000
90"	*62.6	24,900		1,560,000	1,560,000
Concrete pipe—San Joaquin Valley 76" ..	2.74	124,000		340,000	340,000
Walnut Creek Valley 78"	5.90	132,000		779,000	779,000
Sub-total				24,436,000	24,436,000
Contingencies and administration.....				3,665,000	3,665,000
Total for Second Unit—75 M. G. D.				28,101,000	
Total for Third Unit—75 M. G. D....					28,101,000
Total for three units—200M.G.D.					95,574,000

* Duplicated mileage—not counted.

Sacramento River Project

DESCRIPTION

The Sacramento River rises at the base of Mt. Shasta in the northern part of California and flows southward between the Coast and Sierra Nevada ranges into San Francisco Bay. It is the largest river in California, except the Colorado, which forms the southeastern boundary of the state. The principal tributaries of the Sacramento are the Pitt, Feather, and American rivers, all rising in the Sierra Nevada Mountains. Its tributaries from the west are comparatively small. The river, where it emerges from the mountains in the lower end of Iron Canyon near Red Bluff, has a mean annual discharge of nearly 9,000,000 acre feet. Tributaries below this point more than double this quantity, so that more than 18,000,000 acre feet of water are discharged by the Sacramento. The major portion of this water now runs to waste.

Most of the engineers who have studied

water supplies for the Bay Region have discussed the Sacramento River as a possible source and have dismissed it because of its pollutions; but this has usually been after considering only the waters below the City of Sacramento and the irrigated rice fields.

The waters of the Sacramento proper, and also of its large tributary, the Feather River, are, in most years, completely utilized for irrigation during the summer and early autumn, so that it would be impracticable to divert water at these seasons unless a supply were provided by storage of the winter and spring waters that now run to waste.

The Sacramento River Project has been considered under two plans of development, here designated as the Upper Sacramento River Project and the Lower Sacramento River Project. These two plans will be discussed separately.

THE UPPER SACRAMENTO RIVER PROJECT

DESCRIPTION

The Upper Sacramento River Project contemplates the construction of a reservoir in Iron Canyon and the conveyance of the water from the reservoir by gravity in a surface aqueduct of 300 second feet capacity a distance of about 195 miles to the vicinity of Benicia near Carquinez Strait, thence under the strait and into San Pablo and Upper San Leandro reservoirs by pumping. This aqueduct would be operated for the time being from December 1st to June 1st of each year to its full capacity without interfering with existing rights; and, during this period, it would serve the current needs of the District, and at the same time fill the local reservoirs. These local reservoirs, as they now are, would hold more than a years' supply at the present rate of consumption, and their capacity will be nearly doubled by the completion of the upper San Leandro Reservoir now under construction.

When the District's demands for water required its service during the summer, as well as winter, a water supply for this purpose could be provided by building the Iron Canyon Reservoir, or by reservoirs constructed on Pitt River, McCloud River, or Fall River, if found more economical. Another alternative would be the storage of water on Trinity River in a large

reservoir near Fairview and the diversion of this water through the mountain range by a tunnel eight miles in length and the discharge of it into Clear Creek, a tributary of the Sacramento River. A continuous supply of about 600 second feet could be obtained from the Trinity River in this manner and the water would also be available for power development under a head of about 1200 feet.

However desirable in the future development of the District the immediate construction of an aqueduct from Iron Canyon, and storage there, might be, such a plan would be too large for the District's present bonding limit; but a plan can be worked out for developing this plan in steps, the first one of which would be within feasible cost limits. The other steps could then be carried out in the future when the needs demand them and funds become available. By building the aqueduct 69 miles northward from Benicia, to a point about 81-2 miles above Knights Landing at what has been designated as East Bay Point, it would be possible to supply it with water from the Sacramento River above all of the major pollutions. With a pumping plant at this point, and seven miles of pressure pipe across flat country discharging into the aqueduct, the water could be carried into the

District reservoirs as in the general plan. The length of aqueduct from East Bay Point to San Pablo Reservoir would be about 82 miles.

Another alternative is to build the aqueduct northward from Benicia to a point about two miles north of Arbuckle and there supply it with water from the Central Canal by means of an extension constructed for the purpose. The Central Canal heads in the Sacramento River near Hamilton above the worst pollutions of the river. This canal is built on a grade of six inches to the mile, and has a capacity at its head of 1600 second feet. At the lower end of the constructed canal its capacity is about 300 cubic feet per second, and an extension of smaller capacity is now under construction. The lower end of the canal would require both enlargement and extension to reach the aqueduct about two miles north of Arbuckle. This line would be about 96 miles long and would leave about 100 miles of aqueduct to reach Iron Canyon still to be built north of Arbuckle. It is believed that a satisfactory contract can be entered into with the Glenn-Colusa Irrigation District, which owns and operates the Central Canal, by which 300 or 400 second feet of water could be furnished to the District from November 1st to May 1st of each year when the canal is not used, or is only partly used.

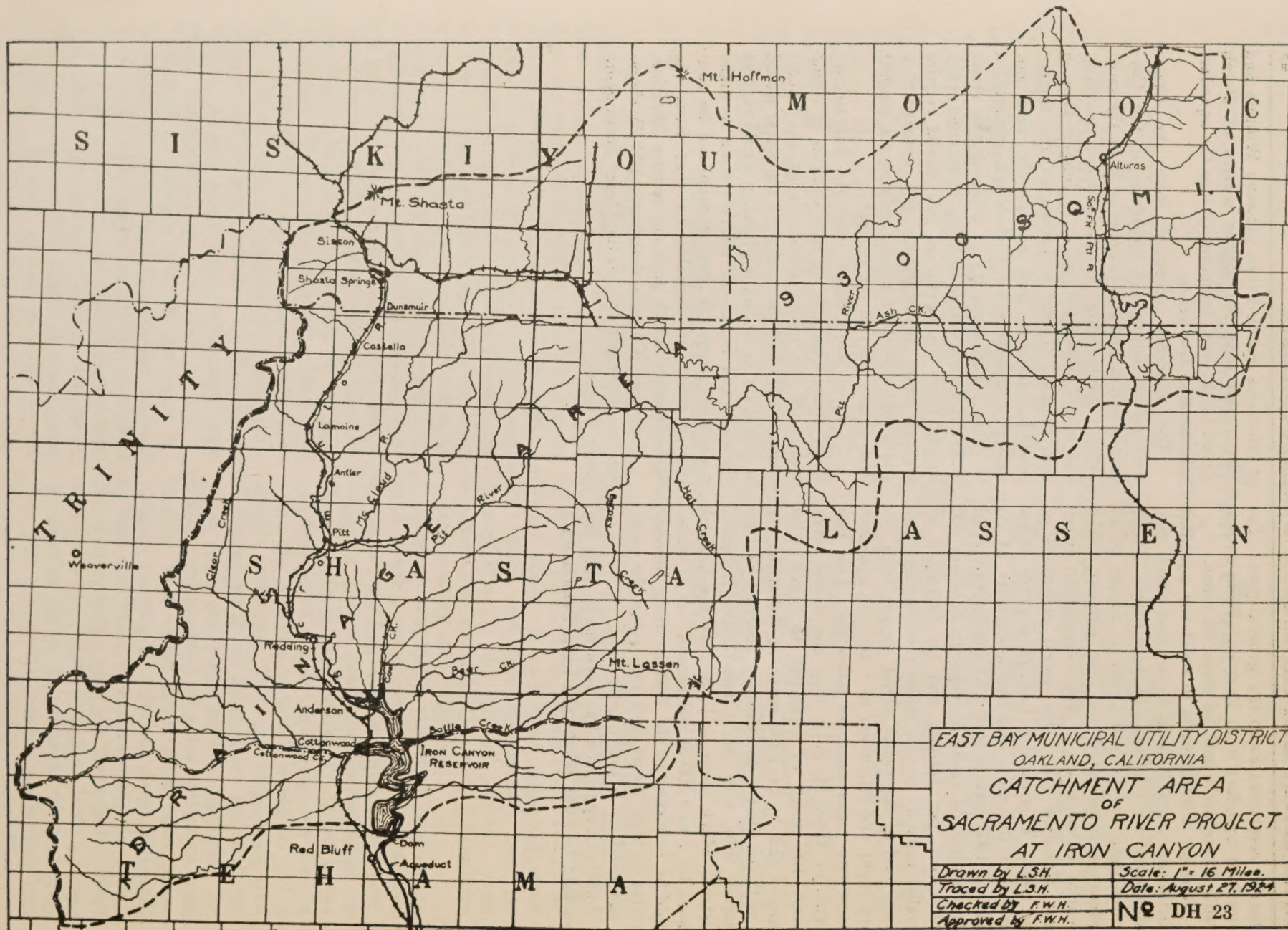
Another suggestion has been made, that the aqueduct be built northward from Benicia until

it intersects Putah Creek between Winters and Davis, and that the winter waters of Putah Creek be diverted temporarily into the aqueduct for the first few years.

The aqueduct proposed from the Upper Sacramento requires a crossing of the Carquinez Strait, and this is believed to be the most difficult engineering feature which it involves, and would probably require the longest time in construction. Little is known of the underground conditions and neither the time nor money is available for a thorough exploration of these. The necessity of crossing this strait makes it impracticable to bring in an emergency supply from the north, as this would require several years investigation and construction, and is probably the feature requiring the longest time of any part of the project.

If water were taken from the Sacramento River above Chico, or at Iron Canyon, it would escape all the major pollutions of the Sacramento Valley and the quality of the water would be relatively good, but it probably would require filtration and treatment with chlorine to make it entirely acceptable; but it could not be considered quite as desirable as that from the Sierra sources which does not require filtration.

Following is a map, designated DH 23, showing the catchment area of the Upper Sacramento River Project.



EAST BAY MUNICIPAL UTILITY DISTRICT
OAKLAND, CALIFORNIA
CATCHMENT AREA
OF
SACRAMENTO RIVER PROJECT
AT IRON CANYON

Drawn by L.S.H.	Scale: 1" = 16 Miles.
Traced by L.S.H.	Date: August 27, 1924.
Checked by F.W.H.	
Approved by F.W.H.	No DH 23

WATER SUPPLY

This report of the water supply available from the Sacramento River for the Upper Sacramento Project at Iron Canyon is based on the report on Iron Canyon Project, California, by Homer J. Gault, Engineer, U. S. Reclamation Service and W. F. McClure, State Engineer of California, published by the U. S. Reclamation Service in May, 1920. This report will hereafter be referred to as the Reclamation Service Report. Following are given the principal assumed conditions on which the water supply study given in that report is based:

- (A) Storage dam located one-half miles below the gaging station in Iron Canyon;
- (B) Elevation of spillway, 392.5;
- (C) Elevation of bottom of canal intake, 340;
- (D) Available reservoir capacity, 640,000 acre feet;
- (E) Irrigation requirement per annum, 928,125 acre feet;
- (F) Reservoir losses per annum, 64,000 acre feet;
- (G) Storage permitted of the natural flow in excess of 6,000 second feet during May, June, July, and August, in excess of 5,000 second feet in April and September, and in excess of 4,000 second feet during the remainder of the year.

The Reclamation Service Report covers a water supply study for the years 1896-1920, inclusive; and this study has been supplemented by bringing it up to date, to include 1924. This revised information shows that the mean annual flow for the period of 1896 to 1924 is 9,489,700 acre feet; that of this amount 3,399,900 acre feet are required to satisfy the assumed prior rights; and the balance available is 6,089,800 acre feet. In addition to the existing prior rights, other applications are continually being made and the low water flow is being so rapidly utilized that very little other than stored water is available during the heavier draft months of the irrigation season. However, there is ample water from December to April always, and very generally from October to May, inclusive, to supply the East Bay District's requirements and the irrigation demands from natural flow. The problem then is the determination of the available supply in the low water season.

For use in determining the available supply in the low water season 200 M. G. D. are assigned, with an assumed priority of right, to the East Bay Municipal Utility District, and the balance is assigned to the development of addi-

tional irrigable lands. The total amount available for these two purposes is fixed at 928,125 acre feet, the amount used in the Reclamation Service Report. The substitution of the East Bay District draft for the irrigation draft will tend to decrease the demands in the peak of the irrigation season and permit greater draft from the natural flow in the non-irrigation season. But this difference is omitted as negligible in its effects of the area of land that can be irrigated with the balance of the water supply as equalized by the Iron Canyon Reservoir.

The Reclamation Report provides for distributing the annual use of water for irrigation as follows:

6% for March	19% for August
10% for April	7% for September
14% for May	2% for October
19% for June	2% for November
21% for July	

The total mean annual supply available for irrigation, after deduction of the East Bay District's requirements, has been distributed in proportion to these percentages.

The Iron Canyon Reservoir is to be controlled by a dam at the river level elevation of 253 feet and flow line elevation of 392.5 ft. The total available storage capacity is 640,000 acre-ft., the grade of the outlet being at elevation 340 feet. A compilation of contour elevations, submerged areas in acres, and the storage capacity in acre feet, is given in Table 20.

The Reclamation Service Report gives estimated losses on the reservoir through exaporation and seepage, on a monthly basis. These losses are used in making calculations on the sufficiency of the reservoir capacity; and, while the draft for the East Bay District will not be exactly comparable with the assumed draft in the Reclamation Service Report for irrigation, they are used without alteration in making this study. The table of evaporation given in the Reclamation Service Report is copied in this report as Table 21.

Giving proper consideration to the probable evaporation and seepage losses on the Iron Canyon Reservoir, the reservoir capacity, the prior rights, the period in which the available run-off is less than the combined demand of the East Bay District and the supply required for the irrigable lands, and the run-off in this shortage period, the total draft at the Iron Canyon Reservoir, the storage capacity required to supplement the available normal flow, and the deficiency of supply, have been computed as shown

in Table 22. This table indicates that during the period from 1895 to 1924 the available water supply was ample to meet the combined demands except in the years 1918, 1920, 1923, and 1924. In these years the following respective deficiencies existed: 36,194 acre feet; 98,127 acre feet; 70,203 acre feet; 613,566 acre feet. The first three of these shortages are not material and could well be absorbed by the decrease of supply for the irrigable lands; but the latter one is so large as to leave only about 153,000 acre feet for the evaporation and seepage losses and irrigation requirements. Since the reservoir would be about empty, the greater part of this would be available for the lands. Since the total annual irrigation draft is assumed to be 703,725 acre feet, the available supply for 1924 would be a little over 21% of the requirement. The supply for the East Bay District would, of course, be complete. This condition can be remedied only by the construction of additional storage either at the source or in the district.

In the matter of development of power, the water capacity of the plant has been assumed at 9,000 second feet at which capacity it could be run on the average for about six months. During the remainder of the year it would, on the average, be run with discharges varying from about 50% to 100% of the maximum capacity. In the study of this power development, the fluctuating head of the reservoir and the monthly discharge thereof have been used to compute the probable H. P. development. The results of this study are shown in Table 23. It will be observed that the average year would yield about 78,300 H. P., which could be used in part to pump the water from the aqueduct into the District reservoirs.

Consideration has also been given to the possibility of furnishing a temporary supply for the conduit from Putah Creek. In connection with this scheme, it may be stated that the proposed conduit line leading from the Iron Canyon Reservoir to the East Bay District crosses Putah Creek at a point about three miles southwest of Davis. In this case a diversion of the waters of the creek into the conduit can be made by means of a low diversion dam and a short canal of about two miles length. Relative to the possibility of obtaining a temporary water supply from Putah Creek for the purpose of diversion into the Iron Canyon aqueduct, it may be stated that in normal years there is a large amount of water available for this purpose. In extremely dry years the supply, however, is greatly reduced.

An inspection of the monthly run-off records of the U. S. Geological Survey will show that the amount of water available during the summer and fall months is very small so that water from this source could be gotten only during the winter and early spring months, but a somewhat comparable condition exists relative to the pumping of water from the Sacramento River itself at East Bay Point. In either case local storage near the District limits would have to be provided to tide over the dry months.

TABLE 20
Contour Elevation, Area, Capacity Data for Iron Canyon Reservoir

Contour Elevation	Flooded Area Acres	Storage Acre Feet
253	0	0
260	229	800
270	341	3,700
280	556	8,100
290	916	15,500
300	1,278	26,500
310	1,751	41,600
320	2,437	62,600
330	3,615	92,800
340	4,750	134,600
350	6,555	191,200
360	9,640	272,100
370	12,863	384,700
380	16,590	531,900
390	21,146	720,600
392.5	22,465	775,100
400	27,178	961,300

TABLE 21
Estimated Mean Monthly Evaporation and Seepage Losses on Iron Canyon Reservoir

Month	Acre Feet
January	150
February	500
March	3,100
April	7,300
May	11,700
June	13,550
July	12,200
August	8,300
September	3,900
October	1,800
November	1,000
December	500
Year	64,000

TABLE 22

**Water Supply for East Bay District and Irrigable Land Development From Sacramento River at
Iron Canyon Reservoir Quantities in Acre Feet**

Year	Period	Run-off at Red Bluff	Prior Rights on Sacramento River	Water Available at Iron Canyon	Total Required Draft and Evaporation and Seepage Loss	Storage Required	Deficiency in Supply
1895	July-Sept.	1,165,000	1,037,000	128,000	411,712	283,712	0
96	July-Sept.	1,148,000	1,030,000	118,000	411,712	293,712	0
97	June-Sept.	1,540,000	1,369,000	171,000	577,413	406,413	0
98	May-Sept.	1,659,000	1,581,000	78,000	706,694	628,694	0
99	May-Sept.	1,704,000	1,584,000	120,000	706,694	586,694	0
1900	June-Sept.	1,188,000	1,188,000	0	577,413	577,413	0
01	June-Sept.	1,202,000	1,197,000	5,000	577,413	572,413	0
02	July-Sept.	886,000	886,000	0	411,712	411,712	0
03	June-Oct.	1,443,000	1,395,000	48,000	612,346	564,346	0
04	July-Aug.	870,000	738,000	132,000	340,108	208,108	0
05	June-Sept.	1,426,000	1,299,000	127,000	577,413	450,413	0
06	July-Sept.	1,201,000	1,034,000	167,000	411,712	244,712	0
07	July-Sept.	1,196,000	1,037,000	159,000	411,712	252,712	0
08	June-Sept.	1,369,000	1,276,000	93,000	577,413	484,413	0
09	July-Sept.	1,103,000	1,018,000	85,000	411,712	326,712	0
1910	June-Sept.	1,294,000	1,277,000	17,000	577,413	560,413	0
11	July-Sept.	1,042,000	998,000	44,000	411,712	367,712	0
12	July-Sept.	976,000	939,000	37,000	411,712	374,712	0
13	June-Oct.	1,612,000	1,510,000	102,000	612,346	510,346	0
14	July-Sept.	1,051,000	996,000	55,000	411,712	356,712	0
15	July-Sept.	1,067,000	1,000,000	67,000	411,712	344,712	0
16	June-Sept.	1,491,000	1,334,000	157,000	577,413	420,413	0
17	June-Oct.	1,543,000	1,437,000	106,000	612,346	506,346	0
18	May-Sept.	1,397,000	1,367,000	30,000	706,694	676,694	36,194
19	June-Nov.	1,580,000	1,538,000	42,000	645,863	603,863	0
1920	May-Oct.	1,492,000	1,489,000	3,000	741,627	738,627	98,127
21	June-Oct.	1,504,000	1,393,000	111,000	612,343	501,343	0
22	June-Oct.	1,419,000	1,324,000	95,000	612,343	517,343	0
23	May-Dec.	2,161,000	2,077,000	84,000	794,703	710,703	70,203
24	Mar.-Nov.	1,860,000	1,815,000	45,000	935,642	890,642	613,566

TABLE 23

Estimated Mean Probable Power Development at Iron Canyon Reservoir

Month	Elevation of Reservoir	Elevation of Tailrace	Head Feet	Dis- charge Sec. Ft.	Horse- power	Kilowatt Hours
January	392.5	287	105.5	9,000	86,400	48,000,000
February	392.5	287	105.5	9,000	86,400	43,400,000
March	392.5	287	105.5	9,000	86,400	48,000,000
April	392.5	287	105.5	9,000	86,400	46,500,000
May	392.5	287	105.5	9,000	86,400	48,000,000
June	391.6	253	138.6	8,560	107,800	58,100,000
July	382.4	253	129.4	8,350	98,300	54,600,000
August	366.4	253	113.4	7,220	74,500	41,400,000
September	360.0	253	107.0	5,810	56,500	30,400,000
October	364.3	253	111.3	4,550	46,000	25,600,000
November	381.1	253	128.1	4,550	53,000	28,600,000
December	392.5	287	105.5	7,410	71,000	39,500,000
Year					78,300	512,100,000

ESTIMATES OF COST OF UPPER SACRAMENTO PROJECT

On page 61 will be found a summary of the estimated costs of the development of the project under two plans, in three units. The first two units in each case provide for all of the works except storage works, and extensions of the aqueduct to the reservoir. The first plan contemplates diverting the water through the Glenn-Colusa Canal until the third unit is needed, and the second plan the pumping of water at East Bay Bend. It should be observed that the first two units under each plan will provide carrying capacity of 100 M. G. D. each, but can be operated only half of the year as the water will be needed for irrigation for the balance of

the time. These units are, therefore, equivalent only to units of 50 M. G. D., and the third unit will be required as soon as the demands for water exceed 100 M. G. D. Prior to that time local storage will also be required to care for the idle pumping season.

The present worth of the estimated cost of the first unit under the second plan is the cheaper and that of the estimated cost of the full development under the second plan is also the cheaper. The present worth of the entire developments under the two plans are \$51,422,000, and \$48,968,000, respectively.

LOWER SACRAMENTO RIVER PROJECT DESCRIPTION

In the Lower Sacramento River Project, it is proposed to pump water from the Sacramento River at a point just north of Rio Vista and south of Newtown. A concrete-lined channel leading from the river under the road would conduct the water to the pump house about 150 feet from the edge of the river. The entrance to this intake channel would be equipped with a grizzly to prevent any large floating objects from entering. A self-cleaning traveling screen would be installed in the channel to remove smaller floating debris and fish. The water would be lifted from the river to a small stilling reservoir in the hills above Rio Vista at an elevation of about 125 feet and at a distance of about two and one-half miles from the pumping station.

From this stilling pond a pipe line would be constructed to a point one and one-half to two miles west of Toland landing on the Sacramento River, where it would extend across low ground for about three-quarters of a mile on wooden piles, then under the Sacramento River, across Sherman and Kimball islands on piling, then under the San Joaquin River to a point just west of Antioch.

From Antioch to Bay Point the line would parallel the railroads and highway, and with the exception of the section through Pittsburg and Bay Point would be carried on top of the ground. Through these towns it would be necessary to bury the pipe. West of Bay Point the line would be parallel to the Santa Fe Railroad right of way and be carried on wooden piles to a point near

the crossing of Pacheco Creek where a second pumping plant would raise the water about 350 feet into a tunnel leading to San Pablo Reservoir, a total distance of about 45 miles. At San Pablo Reservoir a coagulating plant, filter basin and chlorination plant would be installed to render the water fit for consumption. The capacity of the pumping plants and pipe line would be approximately 100 M. G. D., and filter plant 50 M. G. D., as the filter can operate the entire year, while the pumps and pipe line can be used for only five months in the year. An alternate line could be built from a point west of Bay Point connecting with a tunnel in the hills in the vicinity of Lafayette. It would be considerably longer and consequently more costly.

A curve showing the amount of salt in the river at Rio Vista during 1920 (the worst year for which a complete record has been available) will also be found on page 53. Data at hand indicates that 1924 will show a much worse condition than 1920. From these records and from the fact that large tracts of land exist up the river that will eventually be irrigated, it would appear that the salinity of the water in the stream would gradually become worse and worse. The drainage water from irrigation is also increasing, and this water is contaminated by vegetable matter and salts from the soil.

Above Rio Vista the river receives the sewage from several towns, including Sacramento, which alone has a population of over 80,000 and is rapidly increasing in size, as are all the other

towns along the river. The quality of the water is bad at the present time, both for domestic use and industrial purposes, and will continue to grow worse. While it is possible by filtration and chemical treatment to render the water practically harmless, it is not possible to remove the saline and other salts that are carried in solution. It, therefore, appears that the best that can be expected from the Sacramento River at Rio Vista would be a water that, by treatment, would not be harmful and would provide a domestic supply that could carry the district until such time as a mountain source could be developed, without a water famine.

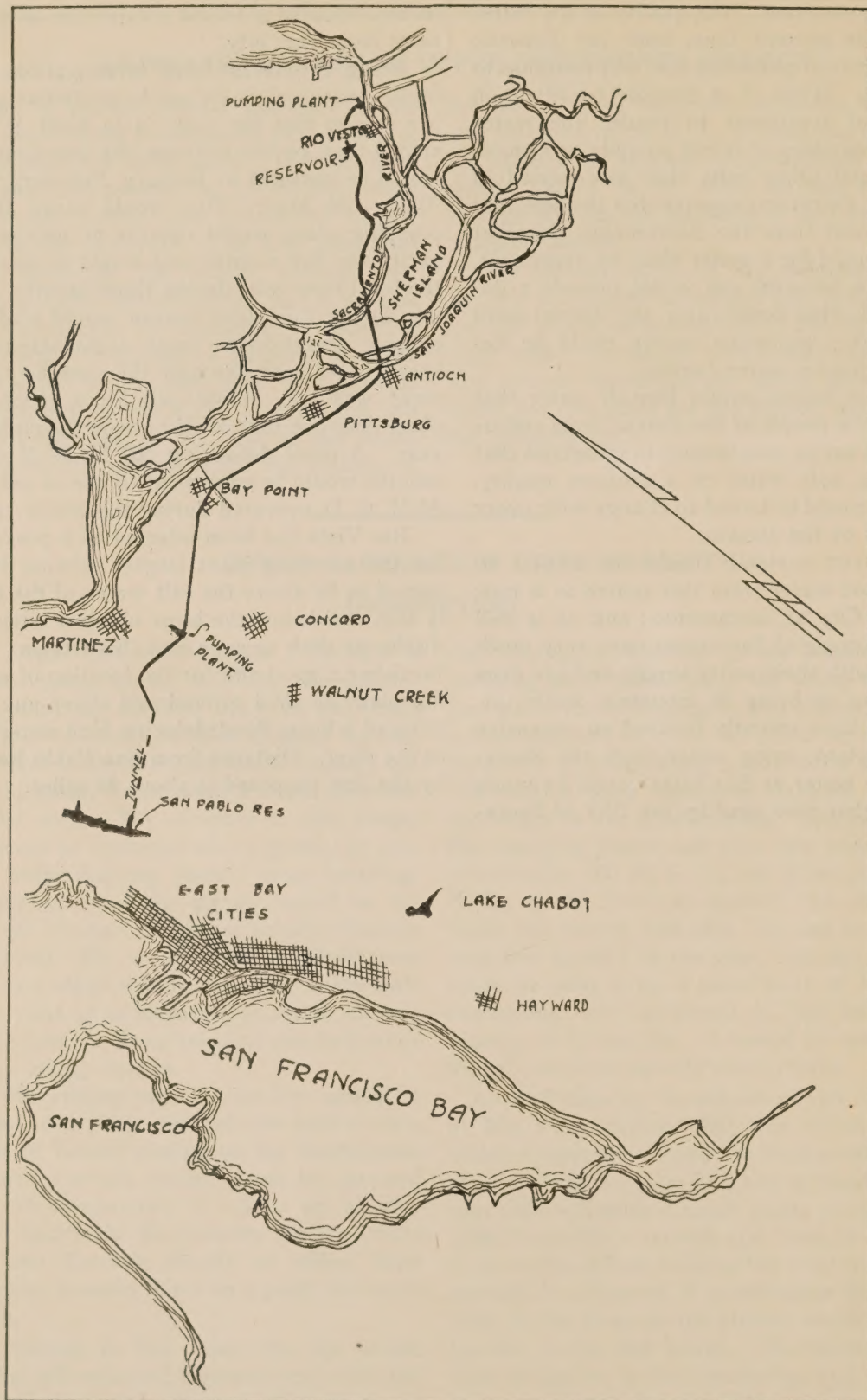
While this source would furnish water that would keep the people of the district from suffering, it would not be satisfactory to industries that require pure, soft water of a uniform quality. The quality would be bound to change with every rise and fall of the stream.

The District certainly could not expect to obtain as good water from this source as is now used by the City of Sacramento; and, as is well known, the people of Sacramento are very much dissatisfied with their water supply and are even now planning to bring in mountain water, although they have recently finished an expensive new water plant, using water from the Sacramento. The water at Rio Vista would be much worse than that now used by the City of Sacra-

mento, because it would receive the large pollutions from that city.

Being convinced from investigations that a usable quality of water can be gotten only during the season that the river is in flood, it is concluded that, on the average, the pumping season would be confined to January, February, March, April, and May. This would mean that the pumping plant would operate at maximum capacity for five months and would be used to fill the local reservoirs during those months. Pumping during this short season would lead to expensive operation as some organization would have to be kept through the months that the plant was idle, would call for a much larger plant than one that could operate throughout the year. A plant delivering 100 M. G. D. for five months would be equivalent to one of only about 42 M. G. D. operated during the whole year.

Rio Vista has been selected as a possible site for the pumping plant largely because it is assumed to be above the salt water of the bay. It is also well below the large up-river cities which discharge their sewage into this stream. It also furnishes a good site for the location of a pumping plant on solid ground and above any probability of it being flooded during high water season of the river. Distance from San Pablo Reservoir by the line proposed is about 45 miles.



EAST BAY MUNICIPAL UTILITY DISTRICT
SKETCH MAP OF PROPOSED RIO VISTA PROJECT

AUG. 14, 1924.

WATER SUPPLY

Most of the records of saline content in the Sacramento River, available, were taken with a view to irrigation requirements rather than domestic water supply, although the City of Antioch, in its suit against the Rice Growers, has secured considerable data on the saline content in the river at that point.

The sugar company at Crockett has a record dating back to 1911, but discontinued in 1920, as the water then got so bad that it made arrangements to bring its water from Marin County across the bay. It was equipped to make tests on a barge in which it brought water from the river to its plant. The barge was run up the river until tests showed that the water was fresh enough for the company's use and was there loaded with water, records being kept of the distance of loading from Crockett. A diagram on page 53 shows these records. As the company treats all its water, it could get along with water of comparatively poor quality.

The increasing use of water for irrigation and the consequent decrease of the normal stream flow, allowing the salt water from San Francisco Bay to gradually reach points higher and higher up, has been discussed so much that it has become a subject of common knowledge and does not appear to need much discussion here.

Taking water from the Sacramento River at Rio Vista would be a very expensive proposition for getting a temporary supply and the best we could say for the quality would be that it could probably be treated so it would not be harmful from a health standpoint. For manufacturing and industrial purposes it would be far from satisfactory and would continually get worse. These conclusions seem to be borne out by the following quotation from the reports of other engineers:

Allen Hazen in Freeman Report 1912, Page 315:

"The water of both rivers (San Joaquin and Sacramento) in their raw state are not suitable for public water supply. They can be filtered so as greatly improve their quality.

"The best way to treat the water is by means of mechanical filtration. The raw water will first be treated with a coagulant and allowed to stand in a coagulating or settling basin for some hours, during which the operation of coagulation will take place and the heaviest part of the matters resulting from it will settle to the bottom of the basin, from which they will be flushed back into the river at intervals. The water will then pass to the sand filters operating at a rather high rate and cleaned mechanically by a reverse current of filtered water.

"After leaving the filters, if thought necessary or desirable, the water may be finally treated with hypochlorite of lime."

C. E. Grunsky, Cory Report, 1914, Page 106:

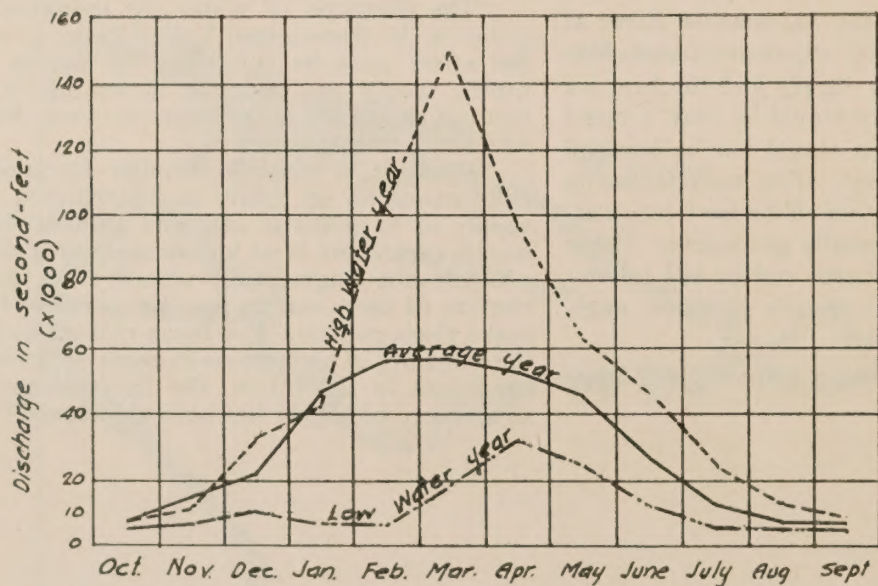
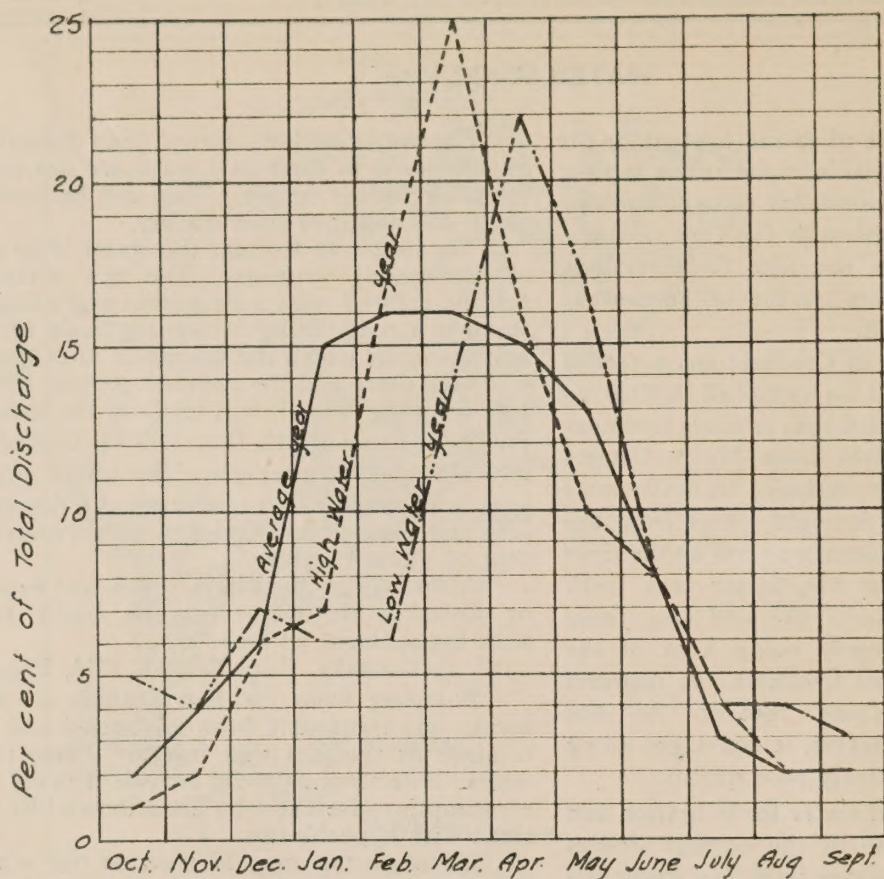
"Pumping from the San Joaquin or Sacramento has frequently been advocated and much is made of the fact that inferior water to that which these streams could provide is made fit for consumption elsewhere by filtration and by treatment with hypochlorite.

"Although this may be true, no one who has the choice would advocate the preparation of a filthy water for domestic use when, within the limit of the means at command a pure mountain water can be made available."

Philip E. Harroun, Report, 1920, Pages 18-19:

"The diversion of water for irrigation purposes in the Sacramento Valley has a very serious effect upon its suitability for use as a domestic supply and with the increasing development of the valley in the years to come this condition will be intensified.

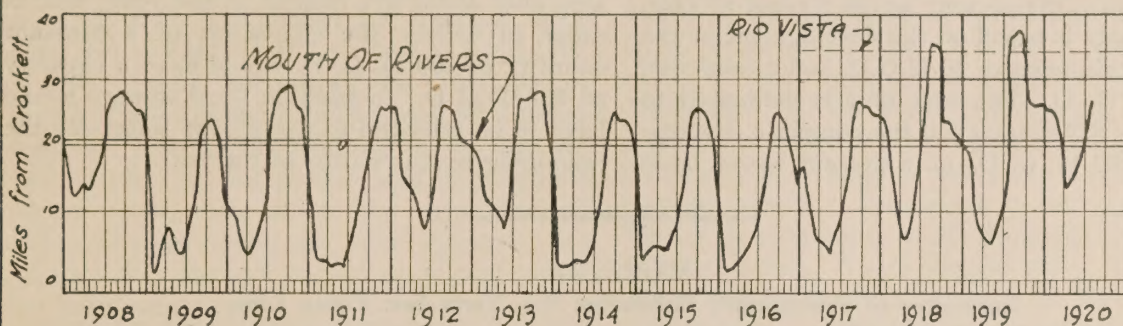
"While it is possible through filtration and chlorination to so purify and sterilize a water supply as to make it safe and suitable for domestic uses, there is no known method in the art of hydraulic engineering whereby the salinity content of these waters may be so reduced as to make them potable. For these reasons and with the certainty of an increase in these objectionable conditions in the future, the Sacramento River as a source of supply has been abandoned."



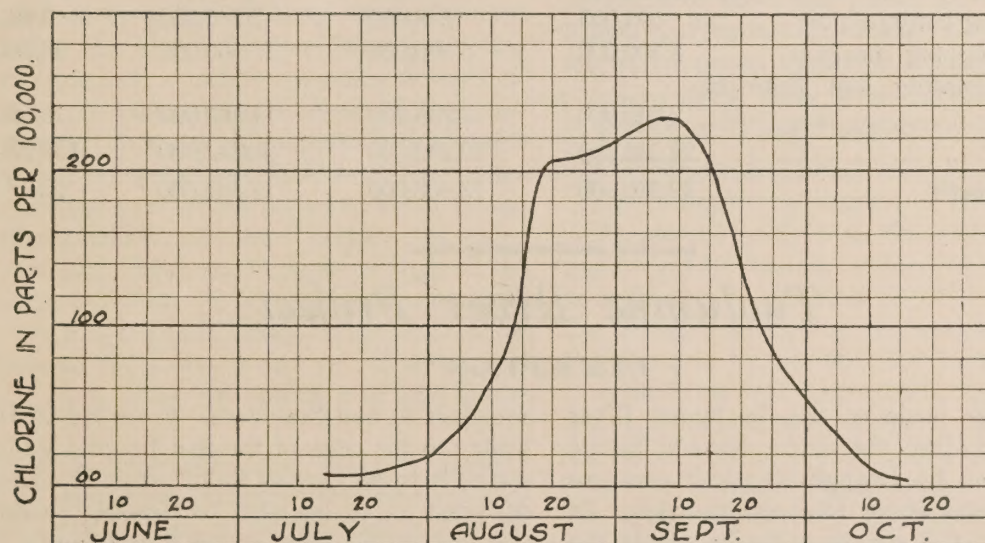
EAST BAY MUNICIPAL UTILITY DISTRICT
OAKLAND CALIFORNIA

CURVES SHOWING DISCHARGE VARIATIONS OF THE
SACRAMENTO RIVER

Data taken
from report
of H.D. McGlashan
to the Sac'to
River Problems
Conference
Jan., 25 & 26-'24.



Average distance upstream from Crockett traveled each month by barges of the California-Hawaii Sugar Co. to obtain suitable water.



CURVE SHOWING SALINITY AT RIO VISTA
IN 1920 DURING HIGH TIDES

EAST BAY MUNICIPAL UTILITY DISTRICT
PROPOSED RIO VISTA PROJECT

AUG. 11, 1924.

ESTIMATES OF COST OF LOWER SACRAMENTO PROJECT

On this page will be found a summary of the estimated cost of the Lower Sacramento Project together with the present worth thereof at 1925. The estimate is based on the development of the project in six units of 30 M.G.D. and a final unit of 20 M. G. D. The first unit is estimated to cost about \$22,280,000 and the complete development of 200 M. G. D., on a present worth basis

a total of \$52,273,000. In this connection, it should be recalled that this plant could be operated only about five months in the year; and, in order to deliver the equivalent of a constant quantity of 200 M. G. D. would have a capacity of 480 M. G. D. In addition, local storage would have to be provided to carry over water for the remaining seven months of the year.

TABLE 24
Summary of Preliminary Estimates Rio Vista-San Pablo Line

Item	First Unit	Second Unit	Third to Seventh Units	Totals
	1924-26		1946-56-64	
		1934	71-77 Each	
Construction periods 30 M. G. D.		30 M. G. D.	30 M. G. D.	200 M.G.D.
Pumping Line—				
225 foot lift at Rio Vista and				
250 foot lift at Walnut Creek				
Estimated cost	13,851,000	10,964,000	54,821,000	79,636,000
Interest during construction.....	693,000	548,000	2,741,000	3,982,000
Capitalized pumping charges.....	5,500,000	5,500,000	27,500,000	38,500,000
Capitalized Treating and Filtering charges	2,236,000	2,236,000	11,180,000	15,652,000
Total	22,280,000	19,248,000	96,242,000	137,770,000
Present worth	22,280,000	12,408,000	17,585,000	52,273,000

Tuolumne River Project

DESCRIPTION

The drainage basin of the Tuolumne River extends high up into the Sierra Nevada Range and contains, at La Grange where it emerges from the foothills, about 1548 square miles. Of this area about 652 square miles lie above the reservoir sites proposed for municipal water supply and 896 square miles below these reservoir sites.

Since the water of the Upper Tuolumne basin comes largely from high mountainous, uninhabited regions it is desirable, potable water and well adapted to general municipal uses.

The Tuolumne River Project, generally spoken of as the Hetch Hetchy Project, contemplates the storage of water in nine reservoirs on the upper drainage area of the Tuolumne River and the conveyance, ultimately, of 400 M. G. D. of water from the Hetch Hetchy Valley in an

aqueduct to San Francisco. From Hetch Hetchy Valley to the edge of the San Joaquin Valley the water is to be carried in an artificial channel so designed as to be used to develop power. At Oakdale, at the edge of the San Joaquin Valley, the aqueduct emerges from the last Sierra Nevada Tunnel, and the plan here considered assumes that the East Bay District will take water at this point from the San Francisco supply and bring it into the District in a separate aqueduct.

The consideration of the Tuolumne River, as a source of water supply for the City of San Francisco and other bay cities, has a long and interesting history, which will not be gone into here. This source was finally adopted by San Francisco in 1913, under the provisions of the so-called Raker Act, which granted the city the right to construct reservoirs at Hetch Hetchy

Valley, Lake Eleanor, and other points in the National Park.

The Raker Act requires the City of San Francisco to recognize and respect the right of the irrigable lands in the Modesto and Turlock Irrigation Districts and vicinity to divert, if available in the river, and needed for irrigation, 2,350 second feet of water from June 14th to April 14th, and 4,000 second feet during the remainder of the year if this amount could be used for storage purposes. The city is required to develop the power incident to this project, and is prohibited from using the water in the bay region for irrigation and from taking any water from the San Joaquin Valley until all its local sources of supply have been exhausted.

Under the above conditions, San Francisco has spent about \$45,000,000 in constructing a gravity concrete masonry dam at Hetch Hetchy, forming a reservoir of 206,000 acre feet capacity, designed for future enlargement to a capacity of 348,000 acre feet; a multiple arch dam at the outlet of Lake Eleanor storing 28,000 acre feet of water, intended ultimately to be built to a much greater height for storing 218,000 acre feet of water; a diversion dam at Early Intake, twelve miles below the Hetch Hetchy Dam; from this point an aqueduct, mainly in tunnel, a distance of about nineteen miles to the Canyon of Moccasin Creek where the water is dropped into a powerhouse a vertical distance of 1,215 feet. The future plans yet require the construction of about seventeen miles of additional tunnel to carry the water from Moccasin Creek to the eastern edge of the San Joaquin Valley, 45 miles of pressure pipes across the San Joaquin Valley, a tunnel 31 miles long through the Coast Range to Irvington, and pressure pipes from this point into San Francisco.

It was Mr. Freeman's plan that an aqueduct would be built from Irvington for the East Bay cities to Lake Chabot, which he proposed to enlarge; and considerable propaganda has been carried on by San Francisco authorities and others to induce the East Bay District to join with San Francisco in the development of the Tuolumne, or what is more legally possible, to purchase water from San Francisco at Irvington gatehouse.

As San Francisco has no water to sell at Irvington gatehouse, and as 48 miles of tunnel and 45 miles of pressure pipes, costing over \$40,000,000, are necessary to carry it there from Moccasin Creek, for which no financial provision has yet been made, this proposition is obviously at pres-

ent impossible. The Raker Act forbids San Francisco to take any water from the Tuolumne River until her local supplies have been exhausted, and these are estimated as sufficient to last her for a long time to come. In addition to this legal prohibition, San Francisco has not the available bonding limit to enable her, if she desired, to construct the 93 miles of tunnel and pressure pipes required to bring the water to Irvington. For the above two reasons, it is impossible to consider purchasing water from San Francisco at Irvington for early use. Hence, consideration has been given to different possibilities of purchasing water from San Francisco at other points. These considerations show that water can be brought to the East Bay District on a shorter and cheaper line by taking it before it enters the Coast Range tunnel and bringing it northward to the foot of Altamont Pass, through a tunnel there 4.7 miles in length, into Livermore Valley, hence across the valley in a surface conduit, and through the hills in another tunnel 5.75 miles in length into Upper San Leandro Reservoir, or when preferred, into Lake Chabot. This would obviate the necessity of the present construction of the Tesla tunnel through the Coast Range, and, as the water must be brought across the San Joaquin Valley in a number of separate pressure pipes, there is no particular advantage in joining with San Francisco on this part of the line either.

Accordingly, on January 3, 1924, negotiations were started with San Francisco to ascertain upon what terms and conditions she would agree to sell water to the East Bay District at or near the Oakdale intake on the eastern edge of the San Joaquin Valley, the plan being for the District to bring the water from that point across the valley in two or three pipes, only one of which would need to be constructed at first. Repeated efforts to obtain a proposal from her have failed. The City Engineer of San Francisco estimates that it will require five years in which to construct the tunnels between Moccasin Creek and Oakdale intake, and this seems to be a reasonable estimate. There is no way of forcing a bond issue, and this District would have no control over the speed or continuity of the work if it were started, and would be taking risks of delay that might be disastrous.

The irrigation districts deriving their water supply from the Tuolumne River have large filings in excess of the yield of the basin upon which they have expended millions of dollars in development, having constructed in the last

thirty years a high diversion dam, a high reservoir storage dam, and a number of smaller reservoirs and extensive canal systems to utilize this water. Their diversions are already in excess of the quantities provided in the Raker Act and only 65 per cent of their lands have been developed. Their needs have been such that they have brought pressure to bear upon San Francisco to sell them stored water from the Hetch Hetchy Reservoir in 1923-1924, and this has been done. If the irrigation interests are permitted to increase their diversions and the consumption of water by 50 per cent, it will largely wipe out the water that the City of San Francisco counts upon taking, and there is no question that they will exert every effort to retain what they claim to be their rights. Whether they can succeed as a matter of law is a legal question, but the policy of thus antagonizing the District's neighbors and customers, upon whose prosperity it in part depends, is worthy of serious consideration.

A considerable part of the irrigation interests agree that San Francisco should obtain a water supply from the Tuolumne River in accordance with her needs and in accordance with the Raker Act, but strenuously object to any participation in this supply by the East Bay District. Their argument is that the needs of San Francisco would not materially interfere with their development, while the enlargement of these requirements, to cover the demands of the East Bay District, would so interfere. San Francisco has large investments in the development of Hetch Hetchy Project, while the East Bay District has none. San Francisco is the owner of works under the Raker Act, and the East Bay District is not. A southern water supply for the City of San Francisco is far more advantageous than a northern one because of the obstacle of San Francisco Bay or the Golden Gate, either of which would be very expensive to cross, and Hetch Hetchy can conveniently approach the city from the south, which is the only direction not having this objection for that city. As these

obstacles do not exist for the East Bay District, their reason for bringing in a supply from the south does not exist, and a more northern supply can be obtained where it will not seriously interfere with irrigation.

The actual cost of completing the Hetch Hetchy project is yet a matter of conjecture. To furnish the amount of storage capacity which would be required for supplying both San Francisco and the East Bay District with an aggregate of 400 M. G. D. would require the completion of the reservoirs at Hetch Hetchy and Lake Eleanor, the construction of a tunnel to connect these two, and the construction of reservoirs on Cherry Creek and in Poopenaut Valley, and several others. The cost of the additional reservoirs, which have not yet been started, is problematical, and very little investigation has been made on this subject. The San Francisco authorities have made no estimate, but, according to the reports, San Francisco has done the natural and proper thing in building the best reservoir sites first so as to defer relatively heavy expenditures as long as possible. This means that the additional reservoir capacity will cost much more per acre foot than the reservoirs already constructed. The Hetch Hetchy Reservoir to date has cost about \$7,000,000 and holds approximately 206,000 acre-feet of water, costing therefore about \$35 per acre foot capacity, and the additional capacity will cost more. If this cost is placed at \$50 per acre foot, the additional storage will cost about \$13,000,000. Of course this cannot be considered an estimate, but in making comparisons it is necessary to make some sort of an assumption. The various tunnels and conduits necessary to make this water supply available at Early Intake are not included in this figure.

Following this page will be found a small map, designated DH 22, showing the catchment area of the Tuolumne River involved in the Hetch Hetchy Project.



EAST BAY MUNICIPAL UTILITY DISTRICT
OAKLAND CALIFORNIA

CATCHMENT AREA
OF
TUOLUMNE RIVER PROJECT

Drawn by: H.B.F.	Scale: 1" = 10 Miles
Traced by: H.B.F.	Date: August 27, 1924
Checked by: F.W.H.	No. DH 22
Approved by: F.W.H.	

WATER SUPPLY

A study of the water supply of the Hetch Hetchy basin, made by Chas. H. Lee, indicates that the basin can be relied upon to yield the priorities belonging to the irrigation districts as defined in the Raker Act and made a condition of the Hetch Hetchy grant, and in addition to these priorities, 370 M. G. D., with a total city reservoir capacity of 804,100 acre feet to meet the requirements of San Francisco and the East Bay District. This study is supported with available stream gaging records, evaporation records, area-capacity curves for principal reservoirs, capacity for small reservoirs, duty of water, diversions of water for irrigation, and irrigable lands.

The proposed reservoirs within the San Francisco portion of the Tuolumne River watershed, used in this study, together with their capacities, are as follows:

Name	Capacity Acre Ft.
Hetch Hetchy	348,000
Lake Eleanor	218,000
Cherry Creek	56,800
Poopenaut	31,000
Lake Vernon	51,000
Huckleberry	52,200
Emigrant Lake	14,300
Tilden	27,800
Wilmer	5,000
Total	804,100

Of these reservoirs the following are built to the capacity shown:

Name	Capacity Acre Ft.
Hetch Hetchy	206,000
Lake Eleanor	27,850
Total	333,850

The net irrigable area of the lands under the Tuolumne River is assumed to be 270,000 acres of which about 30,000 acres are foothill lands and 240,000 valley lands, for which Mr. Lee uses a gross duty of 2.59 and 3.75 acre feet per acre per annum.

The proposed irrigation reservoirs on the Tuolumne River below the San Francisco watershed, are as follows:

Name	Capacity Acre Ft.
Don Pedro	260,000
Dallas-Warner	30,000
Dickinson	60,000
Davis	48,000
Dry Creek (very poor).....	325,000
Empire	35,000
Coffin Hollow	12,000
Lily Lake	15,000
Cottonwood	25,000
Ackerson	26,000
Stone	26,000
Fern Brook	26,000
Heardin	25,000
Big Creek	12,500
Total	925,500

Of these reservoirs the following have been built:

Name	Capacity Acre Ft.
Don Pedro	260,000
Dallas-Warner	30,000
Davis	48,000
Total	338,000

Deducting from the total run-off of the Tuolumne River the irrigation requirements, an annual available supply for San Francisco has been derived from Mr. Lee's report. With this information, Table 25 has been compiled showing the city draft as distributed between natural flow and storage, the regimen of the reservoir system and the waste of water for the period 1911 to 1924. From this table it will be observed that the maximum depletion of stored water would be in 1913 and again in 1924. In 1913, if one-third of the storage is to be held in reserve, that is if 268,000 acre feet is reserved, the depletion would exceed the amount allowed by about 13,000 acre feet. In 1924 the depletion would be about 113,000 acre feet in excess of the allowance.

A study was made also of the period of 1911-13 of the supply available with the four principal reservoirs; namely, Hetch Hetchy, Eleanor, Cherry and Poopenaut. In this case the safe yield is about 336 M. G. D.

TABLE 25

Summary of Gross Water Supply of 400 M. G. D. Including Evaporation Losses or 370 M. G. D. Net Draft Available From San Francisco's Watersheds on Tuolumne River

Year	Run-off From City's Watersheds Acre Feet	Run-off Available for Storage Acre Feet	Draft From Natural Flow Acre Feet	Draft From Storage Acre Feet	Maximum Depletion of Reservoirs Acre Feet	Date of Maximum Depletion	Waste Acre Feet
1911	1,951,315	1,601,599	261,800	187,000	336,248	Apr., 1912	1,339,799
1912	767,163	302,461	75,152	373,648	463,819	Apr., 1913	0
1913	752,181	231,894	112,406	336,394	549,245	Dec., 1913	0
1914	1,696,124	1,100,910	251,424	197,376	236,978	Feb., 1915	289,865
1915	1,259,949	836,604	261,800	187,000	205,117	Feb., 1916	387,804
1916	1,580,001	920,935	240,884	207,916	268,761	Mar., 1917	472,135
1917	1,282,543	876,375	180,039	268,761	260,042	Feb., 1918	427,575
1918	990,487	468,714	151,358	297,442	325,120	Mar., 1919	57,314
1919	922,214	412,290	98,790	350,010	358,447	Mar., 1920	0
1920	963,312	420,115	126,863	321,937	319,807	Feb., 1921	0
1921	1,191,996	657,029	203,050	245,750	276,473	Mar., 1922	134,172
1922	1,548,851	1,215,348	200,865	247,935	302,087	Apr., 1923	738,010
1923	1,169,328	408,600	146,713	302,087	339,400	Mar., 1924	0
1924		26,577	26,577	422,223	649,423	Dec., 1924	0
Means	1,148,247	677,104	166,980	281,820			274,764

TABLE 26

Summary of Net Water Supply of 336.2 M. G. D. From San Francisco Reservoirs on Tuolumne River, Hetch Hetchy, Eleanor, Cherry and Poopenaut Reservoirs

Reservoir	Year	Run-off Available for Storage Acre Feet	Draft From Natural Flow Acre Feet	Draft From Storage Acre Feet	Evaporation From Reservoirs Acre Feet	Lowest Stage of Reservoir for Each Cycle Acre Feet	Date of Lowest Stage	Water Wasted Acre Feet
Cherry	1911	371,267	26,670	19,250	4,930	19,325	Apr., 1912	1,572,504
Eleanor		227,652	54,700	39,480	6,040	143,327	Apr., 1912	170,152
Hetch Hetchy		(1,002,680	133,975	96,690	7,625	169,985	Apr., 1912)	861,160
Poopenaut		(	3,390	2,445	1,490	25,545	Apr., 1912)	
Total		1,601,599	218,735	157,865	20,085	358,182	Apr., 1912	2,603,816
Cherry	1912	74,170	7,760	38,290	4,505	18,834	Mar., 1913	0
Eleanor		36,292	15,827	78,613	5,910	111,208	Mar., 1913	0
Hetch Hetchy		(191,999	38,730	192,570	7,355	133,788	Mar., 1913	0
Poopenaut		(	0	5,850	1,405	18,345	Mar., 1913	0
Total		302,461	62,317	315,323	19,175	282,175	Mar., 1913	0
Cherry	1913	54,684	11,504	34,416	4,485	30,490	Dec., 1914	0
Eleanor		28,737	20,296	73,884	5,435	71,928	Dec., 1914	0
Hetch Hetchy		(148,473	48,439	182,226	6,330	111,197	Dec., 1914	0
Poopenaut		(	0	5,835	1,200	13,440	Dec., 1914	0
Total		231,894	80,239	296,361	17,450	227,055	Dec., 1914	0

Note:—Combined reservoir capacity, 653,800 acre feet; priorities prorated to drainage areas in proportion to run-off.

ESTIMATES OF COST OF TUOLUMNE PROJECT

As in most of the other estimates accompanying this report considerations have been given to a plan of development involving three units of installation of 50 M. G. D., 75 M. G. D., and 75 M. G. D., and to another plan involving two units of installation of 100 M. G. D., each, totaling 200 M. G. D. In the first plan the units are assumed to be constructed in 1924-28; 1942-44; and 1964-66. In the second plan the units are assumed to be constructed in 1924-28 and in 1957-59.

On page 61 will be found a summary of the costs of the various units and their present worths from their mid-construction periods.

None of these costs include the charge that would have to be made by San Francisco for delivering the water to the East Bay District at the Oakdale portal. Following this summary will be found detailed estimates of the costs of the schemes involved which cover different assumptions as to gravity and combined gravity and pumping deliveries. The cheapest plan considered consists of a gravity and pumping line involving a lift of 300 feet, the present worth of which is \$42,265,000 without inclusion of the cost of the delivery of water at Oakdale portal.

Summary of Costs of Various Projects

On the following page will be found a complete summary of the present worths of the estimated costs of the various projects considered. Detailed statements of the bases on which the estimates for each project are made up will be found in connection with discussions of the projects in this report.

TABLE 27

**Summary of Preliminary Estimates for All Sources Reduced to Present Worth at 1926, Including
Interest and Pumping Costs Capitalized at Five Per Cent Per Annum**

Item	American River	Eel River	Mokelumne River	Sacramento River Iron Canyon Rlo Vista	*Hetch Hetchy
THREE UNIT DEVELOPMENT					
Gravity Lines—					
Present Worth—					
1st Unit—50 MGD.....	\$51,943,000	\$45,846,000	\$43,309,000		\$ 32,563,000
2nd Unit—75 MGD.....	13,952,000	7,041,000	12,863,000		10,303,000
3rd Unit—75 MGD.....	4,779,000	2,772,000	4,406,000		3,529,000
Total for 200 MGD.....	70,674,000	55,659,000	60,578,000		46,395,000
Length of aqueduct—miles.....	137.76	141.0	86.1		93.5
Pump Lines—150 foot Lift—					
Present Worth—					
1st Unit—50 MGD.....	48,631,000	38,466,000	40,515,000		31,768,000
2nd Unit—75 MGD.....	12,789,000	9,631,000	10,435,000		8,979,000
3rd Unit—75 MGD.....	4,637,000	3,847,000	3,830,000		3,285,000
Total for 200 MGD.....	66,057,000	51,944,000	54,780,000		44,032,000
Length of Aqueduct—miles.....	138.46	133.8	87.01		93.5
Pump Lines—300 feet Lift—					
Present Worth—					
1st Unit—50 MGD.....		37,680,000	39,624,000		31,927,000
2nd Unit—75 MGD.....		10,218,000	8,295,000		7,431,000
3rd Unit—75 MGD.....		4,052,000	3,242,000		2,967,000
Total for 200 MGD.....		51,950,000	51,161,000		42,265,000
Length of Aqueduct—miles.....		133.7	89.31		95.9
Pump Lines—350 foot Lift—					
Present Worth—					
1st Unit—50 MGD.....				\$41,679,000	
2nd Unit—50 MGD.....				2,687,000	
3rd Unit—100 MGD.....				7,056,000	
Total for 200MGD.....				51,422,000	
Length of Aqueduct—miles.....				195.9	
Pump Lines—60 and 350 foot Lifts—					
Present Worth—					
1st Unit—50 MGD.....				37,328,000	
2nd Unit—50 MGD.....				4,108,000	
3rd Unit—100 MGD.....				7,532,000	
Total for 200 MGD.....				48,968,000	
Length of Aqueduct—miles.....				195.9	
TWO UNIT DEVELOPMENT					
Pump Lines—150 foot Lift—					
Present Worth—					
1st Unit—100 MGD.....		46,528,000	49,894,000		41,166,000
2nd Unit—100 MGD.....		6,144,000	6,207,000		5,725,000
Total for 200 MGD.....		52,672,000	56,101,000		45,891,000
Length of Aqueduct—miles.....		133.8	87.01		93.5
Pump Lines—300 foot Lift—					
Present Worth—					
1st Unit—100 MGD.....		46,913,000	47,976,000		40,016,000
2nd Unit—100 MGD.....		7,081,000	5,509,000		4,981,000
Total for 200 MGD.....		53,994,000	53,485,000		44,997,000
Length of Aqueduct—miles.....		133.7	89.31		95.9
Pump Lines—225 and 250 foot Lifts—					
Present Worth—					
1st Unit—30 MGD.....				\$22,280,000	
2nd Unit—30 MGD.....				12,408,000	
3rd to 7th Units—140 MGD				17,585,000	
Total for 200 MGD.....				52,273,000	

* Estimate covers cost of line from Oakdale Portal to Upper San Leandro Reservoir and does not include any payment to San Francisco for work east of Oakdale Portal.

Water Supply Problem of the East Bay Municipal Utility District

Report by
ARTHUR P. DAVIS
Chief Engineer
East Bay Municipal Utility District
GEORGE W. GOETHALS
Consulting Engineer
WILLIAM MULHOLLAND
Consulting Engineer

Nine cities on the east shore of San Francisco Bay are served, in the main, by the water system of the East Bay Water Company, and, therefore, have a common interest in the water problem. Recognizing this fact, these cities organized themselves into a district, under the state law, for the purpose of securing and increasing their water supply for present and future needs.

The history of recent years shows that this region has not an adequate, reliable water supply and none that can be relied upon to meet the natural growth of future years. The surplus supply has never been large, and the district has at times been on short rations. Industries have, consequently, sought other locations, and in some cases those which have located near here have found themselves in serious trouble for lack of water in sufficient quantity and of suitable quality. Such a condition is destructive of the natural, legitimate growth, and is actually perilous from considerations of fire and of other results of threatened water shortage. The present dry year has made these conditions acute and furnishes an illustration of the peril in which the district has been for many years.

When water is supplied by privately-owned systems, as in the case of this district, it is not commercially possible for the owners to undertake the development of large reserves necessary to insure the communities against future shortage. When this is not done, large industries must either provide their own water supply, or seek other locations, for, with a water famine always imminent, they are confronted with the certainty that, when a shortage arises, domestic uses will be given the preference, and they will be deprived of their needed supplies. Consequently, industries are attracted to localities which can assure them generous supplies for a long period to come, with a reserve in sight, or which can be quickly developed, beyond the probable needs.

Municipalities interested in their own growth

and development are warranted in spending large sums for this assurance, for which they are recouped by the growth of industries and population. This is particularly true of the Bay Cities, at the expense of which other communities recognizing this fact, have profited, even where the natural advantages for industry are far less.

The time has come when it is imperatively necessary for the East Bay District to undertake, as quickly as possible, the provision of a large and generous water supply of a high degree of purity, and to end, once and for all, the danger of water famine that has been hanging like a millstone around its neck for the past generation, impeding the growth of the cities and threatening their very existence.

If this be not done by the District, then the communities will face the possibility of having imposed upon them such a supply as is offered by the Rio Vista on the Lower Sacramento, which, while discussed in the accompanying report of the Chief Engineer, is extremely undesirable.

Information Available

Investigations for bringing a distant water supply to the Bay Region have been conducted from time to time for more than thirty years, mainly at the expense of and for the benefit of San Francisco. The present importance of the East Bay Region is largely of recent growth.

In 1912 Mr. John R. Freeman compiled and studied the existing data accumulated by previous investigations and condensed them into a report dated July 15, 1912. He based his studies upon the assumption that a supply of 400 million gallons daily would be required, which immediately eliminated a number of the smaller streams which might have been found attractive as sources for a smaller quantity of water. Mr. Freeman's studies led to a recommendation for the development of the Tuolumne River, with storage reservoirs in Hetch Hetchy Valley and Lake Eleanor.

This board has had the advantage of the studies and compilations made by Mr. Freeman and his predecessors, and of surveys and studies made later by various other authorities, including those of the East Bay Water Company and of Snow Mountain Water & Power Co., on Eel River sources; those of the United States Reclamation Service and the Sacramento Valley Development

Association on the Sacramento River; and extensive investigations by other parties on the American and Mokelumne rivers.

This information has been supplemented by surveys made during the last four months by the engineers of the East Bay Municipal Utility District. The existing information has been condensed by the Chief Engineer of the District into a report which is attached hereto.

We have spent about ten days in a rapid field reconnaissance of the four most promising sources—the Tuolumne, or Hetch Hetchy Project; the Mokelumne, or Lancha Plana Project; the various alternatives of the Sacramento Project; and the Eel River, or Snow Mountain Project. In addition to this, we have carefully studied the report of the Chief Engineer and the data upon which it is based.

Preliminary estimates for the purpose of comparing the various proposed sources have been made during the last four months by the engineers of the District and we have scrutinized the bases on which they are founded. With the time and money available for the investigation of so large a field, they are, of necessity, general in character, but we are satisfied that they are ample for a decision as to a choice of a source of water supply, and are safe and conservative as a basis for the necessary bond issue. More detailed estimates, based on the design of structures, must be made, however, for purposes of construction.

The engineers of the District have made studies of water supply for the four projects above enumerated, and these appear to be conservative and as conclusive as existing data will permit.

In considering the water supply problem presented this board has recognized the requirements of the case to include careful consideration of the following elements:

1. A liberal supply must be brought to the District as quickly as possible, and it is desirable that a moderate emergency supply be available still more quickly, without undue extra expense.

2. The supply should be as large as it is practicable to bring in with available funds, and susceptible of economical increase in the near future to a much larger amount, preferably 200 M. G. D., or more.

3. The supply must be physically reliable and as free as possible from legal entanglements.

4. The supply must be brought in without peradventure of failure within the present bond-

ing limit of the District. This is the most important of all the requirements.

The present bonding limit has been assumed at \$64,000,000, based upon the present assessed valuation of the District. The board has assumed that \$25,000,000 of this should be reserved for the purchase, repair, and extension of the present distribution system, or such part thereof as is used and useful to the District. This leaves \$39,000,000 as the outside limit of the funds that can be made available for the construction and delivery of a distant water supply.

The particulars concerning each of the sources considered are given in the accompanying report by the Chief Engineer, and the accompanying estimates made by the engineers of the District, which we find have been carefully and skillfully prepared, and reliable for the purposes intended.

The advantages and disadvantages of each source have been carefully studied, and as a result thereof, we have concluded that the best available source of a water supply for this District is the Mokelumne River, to be utilized by the construction of a high dam near Lancha Plana, about thirty miles northeast of Stockton, and of an aqueduct from that dam to the reservoirs now supplying this District, as outlined in the description of the Mokelumne Project. This conclusion is reached from the following considerations:

1. The supply is the nearest of any of which the quality is satisfactory.

2. In its ultimate development to a satisfactory magnitude, it is the cheapest available.

3. The contemplated plans stimulate and assist in the development of irrigation and local domestic water supply; and the project is free from legitimate criticism of its relation to local interests.

4. The contemplated plans are adapted, better than on any other project, to use without waste in bringing quickly to the District a temporary pumped supply from the winter waters of the San Joaquin River.

5. The drainage basin is practically uninhabited and unpolluted and devoid of natural resources likely to attract material development and consequent pollution, and is protected by forest reserves.

The above considerations justify us in declaring the designated source to be the quickest, the cheapest, the purest, the safest, and the best supply available.

We are of the opinion that a supply of fifty million gallons daily can be obtained from the

Mokelumne River by the construction of the first unit of this project at an expenditure of about \$39,000,000.

It is our opinion that, by this plan, water can be delivered to one or more reservoirs now serving the district within four years from the time the above sum is made available for the purpose.

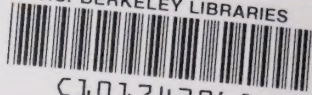
In view of the above facts, we recommend that a bond issue of \$39,000,000 be authorized for

the acquisition and construction of the Mokelumne Project, and that the engineers of the District be instructed to prepare construction plans for the necessary structures as early as possible.

(Signed)

ARTHUR P. DAVIS,
GEO. W. GOETHALS,
WM. MULHOLLAND.

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